MINING engineering

JULY 1955

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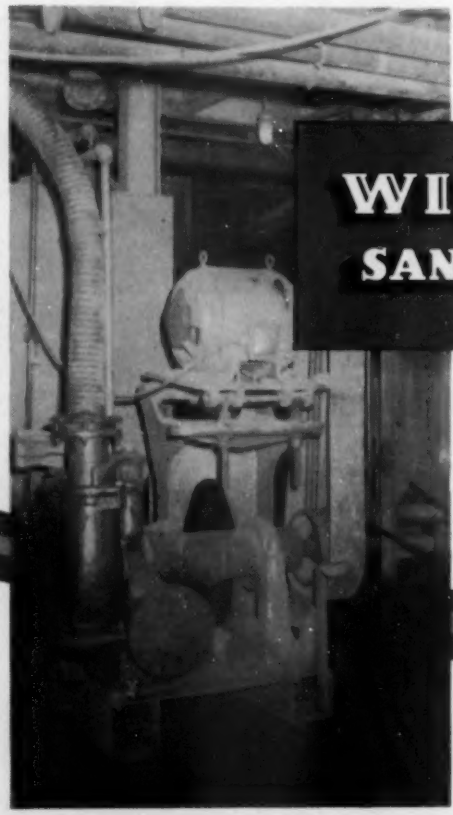
Wilfley Acid Pump
"COMPANIONS IN ECONOMICAL OPERATION"
Wilfley Sand Pump



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MINING engineering

VOL. 7 NO. 7 JULY 1955

COVER

Highest headframe in the world is only part of the story of the Outokumpu Co.'s new Keretti shaftplant in Finland. For the story of the mining methods, hoist installation, and mill see the article starting on page 623.

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PERSONNEL

THE following employment items are made available to AIME members on a nonprofit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

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Maintenance Project Engineer, who can assist an engineering department in obtaining data on mining machines and allied electrical equipment used in the mining industry. Salary open. Location, South. W987.

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WANTED: Young metallurgists or chemical engineers, either recent graduates or with a few years' experience, for process control and experimental test work in metallurgical laboratory and pilot plant operated in close liaison with country's largest uranium ore processing plant involving both carbonate and acid leach sections at Bluewater, New Mexico. If interested write direct to J. B. Knaebel, Manager, The Anaconda Company, Grants, New Mexico, giving full details of education, experience, family status, professional interests, availability and salary expected.

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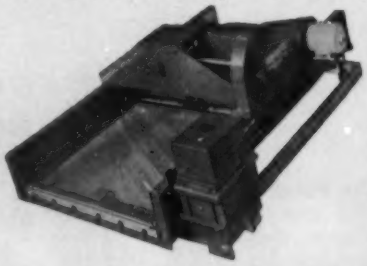
The Li Foundation, Inc. has established two post-graduate fellowships of $2,000 each, for 1955-56, leading to a Master's Degree at The Mackay School of Mines. They are open to citizens of the United States, and may be renewed for a second year.

Send letter containing names and addresses of 3 references, statement of academic and professional record, and recent photograph to: Vernon E. Scheid, Dean, Mackay School of Mines, University of Nevada, Reno, Nevada.

New Model E Leahy® Screen Opens New Range of Applications



An entirely new jacket assembly and mounting concept on the Leahy speeds and greatly simplifies screen tensioning and jacket changes. Reflected to FlexElex jacket heating the new features provide unmatched mechanical, electrical and thermal efficiencies. The new Model E is now unquestionably the simplest and most versatile screen in the fine mesh screening field. Send for complete data and information.

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BOOKS

Petrographic Mineralogy, by Ernest E. Wahlstrom, *John Wiley & Sons Inc.*, $7.75, 408 pp., 1955.—For the student or professional investigator using polarizing microscope techniques in the petrographic laboratory. A comprehensive review of techniques, with descriptions of minerals, determinative tables, and summaries of rock classifications. Profusely illustrated with photographs and diagrams. Full reference material is given.

Introduction to Physical Geology, by Chester R. Longwell and Richard Foster Flint, *John Wiley & Sons Inc.*, $4.95, 432 pp., 1955.—New text for beginning students in geology. Fully illustrated.

The Physical Chemistry of Silicates, by Wilhelm Eitel, *University of Chicago Press*, $30.00, 1592 pp., 1954.—This comprehensive treatise surveys all known facts on the reactions and constitution of silicates. Indices are provided and bibliographical footnotes are keyed to a list of 714 periodicals cited.

Plant and Process Ventilation, by W. C. L. Hemeon, *Industrial Press*, $9.00, 437 pp., 1955.—Methods for analyzing factory ventilation problems, the dynamics of the air pollution process to determine quantities of ventilating air needed, and the best methods for channeling air. Given are behavior of contaminants in air; ventilation for bulk materials handling systems and hot processes; design of duct systems, exhaust systems, and related equipment. Tabular or graphical summaries are provided to meet the needs of the plant engineer.

Please Order the Publications Listed Below from the Publishers

Bibliography and Index of Literature on Uranium and Thorium and Radioactive Occurrences in the United States, Part 4: Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas, by Margaret Cooper, Div. of Raw Materials, U. S. Atomic Energy Commission, 50¢, 70 pp., March 1955.—For geologists and laymen interested in uranium prospecting. Available from *The Geological Society of America*, 419 W. 117th St., New York 27, N. Y. (**Part 1: Arizona, Nevada, and New Mexico,** 25¢, **Part 2: California, Idaho, Montana, Oregon, Washington, and Wyoming,** 25¢, and **Part 3: Colorado and Utah,** 50¢, are still obtainable.

Nuclear Power Reactors, Volume II, Superintendent of Documents, *U. S. Government Printing Office*, Washington 25, D. C., 15¢, 30 pp., March 1955.—A report to the U. S. Atomic Energy Commission by the nuclear power staff of Foster Wheeler Corp., New York, and Pioneer Service & Engineering Co., Chicago.

Geology of Mineral Deposits in the Ubehebe Peak Quadrangle, Inyo County, California, by James F. McAllister, *California Div. of Mines*, Ferry Bldg., San Francisco 11, Calif., $2.00, 63 pp., 1955.—This well-illustrated report deals particularly with lead-zinc-silver, gold, copper, and tungsten mines. Included is an annotated list of 75 minerals found in the quadrangle.

The Mining Journal Annual Review, *The Mining Journal Ltd.*, 15 Wilson St., Moorgate, London, E. C. 2, England, $1.00 postpaid, 300 pp., 1955.—World events in mining in 1954. More than 100 articles on technical advances, finance, metals, and progress reports on the British Commonwealth's principal mining companies, as well as on other mining and investment companies.

Occupational Impairment of Hearing, A Legal Survey, by Theodore C. Waters, *Industrial Hygiene Foundation of American Inc.*, Mellon Institute, 4400 5th Ave., Pittsburgh 13, Pa., $1.00, 17 pp., January 1955.—Mr. Waters, general counsel for the Foundation, has prepared this report to fill the need for reference material on existing laws providing compensation for impairment of hearing. References are given, in summary form, to judicial decisions concerning state compensation statutes dealing with impairment of hearing.

Geology and Mineral Deposits of Lake Valley Quadrangle, Grant, Luna, and Sierra Counties, New Mexico, by Henry L. Jicha, Jr. Bulletin 37, *State Bureau of Mines & Mineral Resources, New Mexico Institute of Mining & Technology*, Campus Station, Socorro, N. M., $2.00, 93 pp., 1954.—A once important mining area at the turn of the century, the "rich bodies of oxidized lead, zinc, and silver are now for the most part worked out or not mineable on an economic basis . . . . The mining of manganese ores in the Lake Valley district is in progress (since early in 1954) in conjunction with the current Government program of strategic minerals procurement."

Industrial Hygiene Foundation of America, 19th Annual Meeting, 1954, Transactions Bulletin 28, *Industrial Hygiene Foundation of America*, Mellon Institute, 4400 5th Ave., Pittsburgh 13, Pa., $5.00, 241 pp., 1955.—Among the papers presented in Pittsburgh Nov. 17 to 18, 1954 were: "Industry's Responsibility in Civil Defense," "Medical Evaluation of Noise," "Hazards of Radioactive Materials," "Health Hazards in Uranium Milling," and "Heat, Mist, and Noise."

(Continued on page 600)

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Reduce mining exploration costs with the Worden Gravity Meter — world's smallest precision instrument for accurate gravity measurement. Manufactured exclusively by Houston Technical Laboratories, the lightweight Worden Meter (5⅛ lbs.) accurately pin-points gravity anomalies. Indicating variations in mass, these anomalies help delineate mineral beds, greatly reducing the amount of diamond drilling and crosscutting necessary for exploration.

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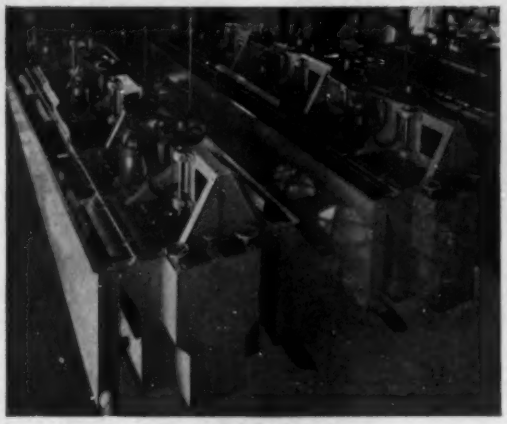
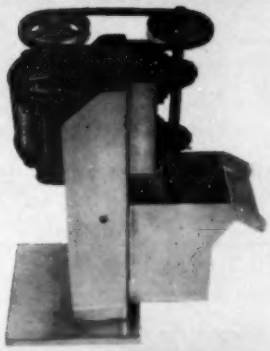
AIRFLOW

Flotation Machine





refer your flotation machine requirements to

The Minerals Separation AIRFLOW flotation machine, for years the "work horse" in Florida phosphate flotation plants, is now available through FRAMCO Products Division of Frank M. Murphy & Associates, Inc. FRAMCO Products offer to the mining industry, for the first time, a complete line of AIRFLOW machines for use in both laboratory and commercial operations.

The AIRFLOW machine was developed after years of extensive experimentation and testing, by Minerals Separation North American Corporation, one of the world's leading authorities on flotation.

Processing ores of continuously lower grades has focused the attention of the mining industry on a need for greater economy in flotation. The primary objective in the development of the AIRFLOW cell was to provide the industry with a high capacity, low cost machine possessing top efficiency in selective metallurgy.

Years of continuous plant operations on numerous ores have proven the AIRFLOW machine to be the most economical flotation cell per ton of capacity available today. The metallurgy, in the grade of the final product and in the recovery of the ore values, has been unsurpassed. The performance of the cells is clearly indicated by the fact that seven of the eight mining companies operating in the Florida phosphate field today are using AIRFLOW machines in their flotation circuits.

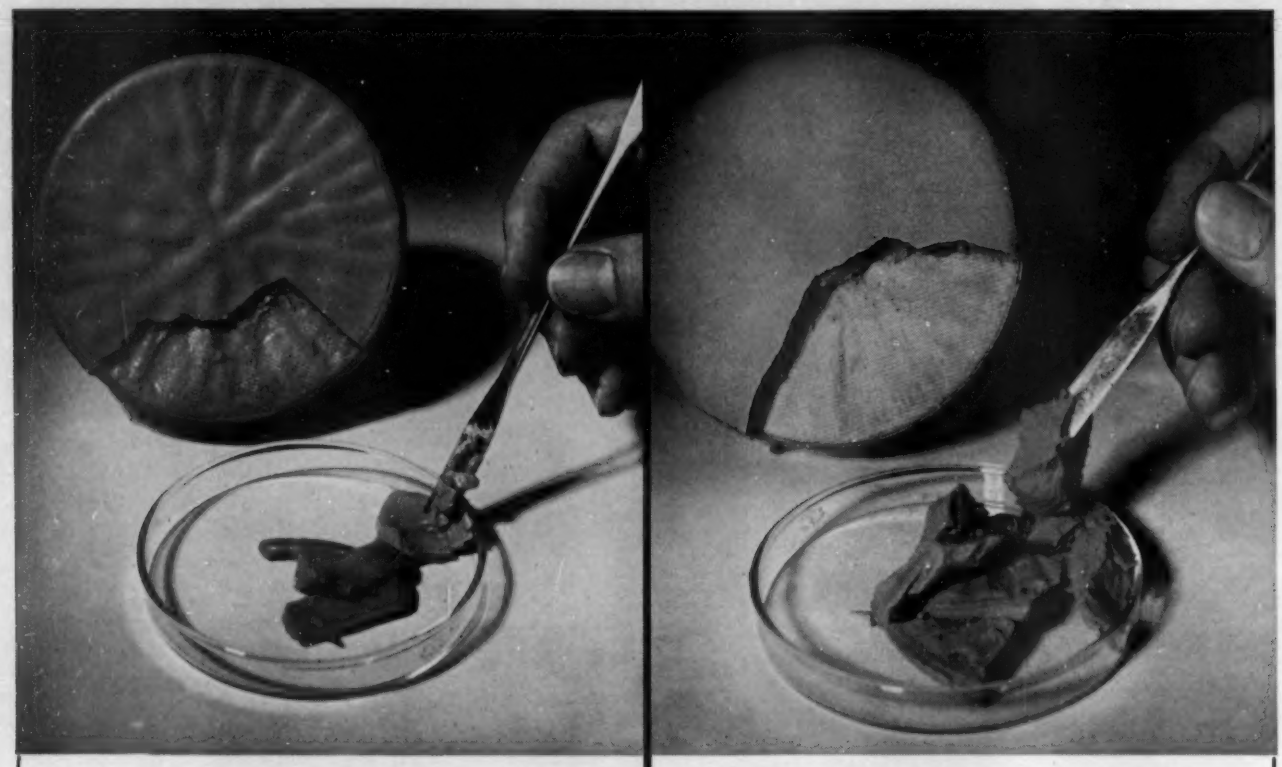
The Minerals Separation AIRFLOW cell introduced a new principle in positive aeration of an ore pulp which results in higher capacity and more efficient operation. The basic design features and superaeration obtained in the AIRFLOW cell offer many advantages in both lower operating costs and improved metallurgy that can not be equaled in any other type flotation machine.

Successful plant operations have established the dependability and superior metallurgy performance of the Minerals Separation AIRFLOW flotation machine. We invite your investigation of our product.

FRAMCO Products Division
Frank M. Murphy & Associates
Barrow, Florida

Separan 2610

GREATLY IMPROVES FILTRATION



Above picture shows thin cake formed on filter with untreated solids. Cycle includes 15-second cake formation and 45-second drying time.

During the same cycle, a much thicker cake is formed by treating with 0.15 lb. of SEPARAN 2610 per ton of dry solids present.

New flocculating agent speeds up filtration and settling rates, brings many other improvements to liquid-solid separations

THE DOW CHEMICAL COMPANY
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Please send me information and a trial sample of SEPARAN 2610.

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Company_____

Address_____

City_____ State_____

Prove to yourself the advantages of Separan* 2610 in filtration.

1. Increased cake size
2. Decreased cake moisture and better washability
3. Easy to handle and less dusty cake
4. Less material loss in filtrate
5. Effective over wide pH range

Prove to yourself the advantages of Separan 2610 in settling.

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2. Increased overhead clarity
3. Less materials loss in overhead
4. Reduced cost in acid and alkaline media
5. Increased plant capacity

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- Borax
- Cement
- Alum
- Potash
- Foundry Sand
- Coal
- Phosphoric Acid
- Iron Ore and Taconite
- Industrial Water, and Waste
- Miscellaneous Metals

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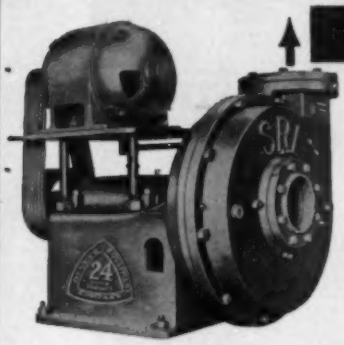
DOW

DENVER Pumps Save You Many Dollars In Power, Maintenance and Continuous Operation



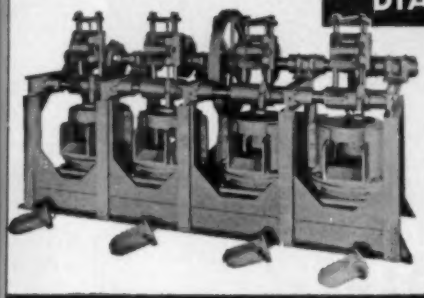
SRL SAND PUMPS

DENVER SOFT RUBBER LINED SAND PUMPS lower pumping costs 30% to 70% due to simple design, lighter weight and accuracy of rubber parts which increase efficiency 1½ to 3 times over other sand pumps.

Denver Soft Rubber Lined Pumps have molded rubber impellers and casing liners for long life.

Size	Gals. of Water per Minute		20′ head	40′ head	60′ head	80′ head	100′ head
2″ x 2″	50	RPM	838	1090	1320	1525	
SRL		HP	.60	1.5	2.8	3.2	
3″ x 3″	100	RPM	760	1053	1303	1453	
SRL		HP	1.1	1.9	3.4	4.3	
5″ x 5″	300	RPM	590	800	985	1087	
SRL		HP	2.4	5.4	8.3	11.5	
6″ x 6″	1000	RPM		862	1005	1122	
SRL		HP		14.4	22.6	30.0	
8″ x 8″	150	RPM	870	1145	1385	1580	1745
SRL-C		HP	1.5	3.2	5.3	7.2	9.6
5″ x 4″	350	RPM	655	850	1020	1160	1280
SRL-C		HP	2.9	5.4	8.3	11.4	14.5
8″ x 6″	800	RPM	500	655	780	890	980
SRL-C		HP	5.7	11.6	16.8	22.3	28.6
10″ x 8″	2000	RPM	485	610	710	800	855
SRL-C		HP	14.0	27.8	41.2	56.3	71.6

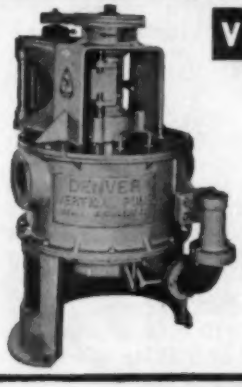
(*Multiply these horsepower ratings by the specific gravity of your pulp to determine actual brake horsepower required.)



DIAPHRAGM PUMPS

DENVER ADJUSTABLE STROKE DIAPHRAGM PUMPS are available in either simplex, duplex, triplex or quadruplex units. Ability to adjust the stroke while pumping makes pump particularly valuable on thickeners. Pumping stroke is vertical and prolongs diaphragm life.

Size	Type	Capacity Cu. Ft. per Min.	Motors H.P.
2″	Simplex	2.42	¾-1
2″	Duplex	4.84	1½-2
3″	Simplex	4.69	1½-2
3″	Duplex	9.38	2-3
4″	Simplex	5.98	1½-2
4″	Duplex	11.96	2-3
5″	Simplex	18.0	2-3
5″	Duplex	36.0	5-7½
6″	Simplex	23.0	3-5
6″	Duplex	46.0	5-7½
6″	Triplex	69.0	10-15
6″	Quadruplex	92.0	15-20



VERTICAL CENTRIFUGAL PUMPS

DENVER VERTICAL CENTRIFUGAL SAND PUMPS are ideal for handling frothy liquid or coarse sandy material. Sizes: ¾″, 1″, 2″, 3″ and 4″. No sump or feed box is required. Handles any material that will flow by gravity. Self priming, no sealing water is required.

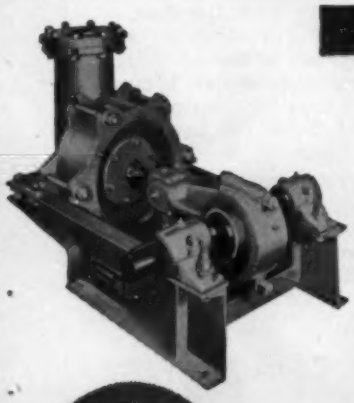
Vertical design protects motor from splash. Long service from wearing parts. Handles intermittent flows.

Capacity Based on 25% Solids By Weight

Discharge Head—Vertical Lift Plus Friction Head

Pump Size	Gal. Per Min.	—20 Ft.— RPM	HP*	—30 Ft.— RPM	HP*	—40 Ft.— RPM	HP*	—60 Ft.— RPM	HP*
¾″	15	1975	½	2385	1	.....	...	.....	...
1″	30	1150	¾	1450	1½	1824	2	.....	...
1½″	75	1015	2	1230	3	1410	3	1710	7½
2″	150	1000	3	1200	5	1370	7½	1660	10
3″	225	825	7½	925	7½	1035	10	1250	15
4″	450	690	10	775	15	855	15	1015	20

*Motor Horsepower



SUCTION-PRESSURE PUMPS

DENVER SUCTION-PRESSURE DIAPHRAGM PUMPS solve special problems where elevation is involved. They are also ideal for filtrate pumps or where metered flows are required. Variation of stroke is possible with adjustable eccentric. Available in acid-proof construction if required. Rugged construction makes this pump valuable in many difficult jobs.

Pump Size	Type	Speed Range R.P.M.	Speed Range Stroke	"Capacity—Maximum Stroke—40 R.P.M. Cu. Ft. Per Min.	"Capacity—Maximum Stroke—40 R.P.M. Gallons Per Min.
¾″	Simplex	40-60	0″ to 1″	0.31	2.3
1¼″	Simplex	40-60	0″ to 1⅛″	0.67	5.0
1¼″	Duplex	40-60	0″ to 1⅛″	1.34	10.0
1¼″	Triplex	40-60	0″ to 1⅛″	2.10	15.0
1¼″	Quadruplex	40-60	0″ to 1⅛″	2.70	20.0
2″	Simplex	40-60	0″ to 1¾″	2.40	18.0
2″	Duplex	40-60	0″ to 1¾″	4.80	36.0
2″	Triplex	40-60	0″ to 1¾″	7.20	54.0
2″	Quadruplex	40-60	0″ to 1¾″	9.60	72.0
4″	Simplex	40-60	0″ to 2½″	5.90	44.0
4″	Duplex	40-60	0″ to 2½″	11.80	88.0
4″	Triplex	40-60	0″ to 2½″	17.70	132.0
4″	Quadruplex	40-60	0″ to 2½″	23.60	176.0

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You Get Your Round in Faster

...and lower your drilling costs with a CLEVELAND Air Leg and Drill Combination

Cleveland Air Legs and Drills have these important essentials — easier handling, higher drilling speed, and sturdy dependability — that enable your miners to increase the footage they can drill per man-shift.

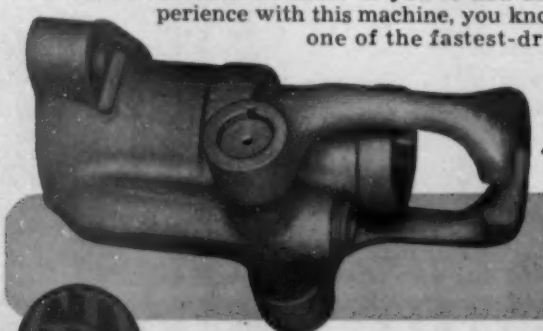
Here's why Cleveland Air Legs and Drills are easier to handle — Only Cleveland gives you an air leg and drill with a built-in 11-position feed control. It eliminates a third hose and cumbersome "Y" connections, reducing the weight a miner has to handle. No feed-control bleed valve is required either so that the operator doesn't have to bleed off air continuously to maintain suitable feeding pressure. And a new, quick-opening steel puller makes steel changing easier and faster.

Here's why Cleveland Air Legs and Drills have higher drilling speed — First of all, the Cleveland Air Leg uses the Cleveland H-10 drill. If you've had any experience with this machine, you know it's one of the fastest-drilling sinker drills made today. Then you have the built-in feed control that provides 11 feeding positions from zero to full-line pressure — with an increase of 9 psi at each setting. It lets the operator adjust the feed so that the drill is always down on the collar of the shank for maximum drilling speed, regardless of varying rock conditions.

Here's why Cleveland Air Legs and Drills stay underground longer — The Cleveland H10 drill is a proved performer, not only in the matter of drilling speed but also in upkeep cost. It's built to take it. And the Cleveland Air Leg holds the drill in line with the hole — thus reducing front-end drill wear and practically eliminating rotation strains. Moreover, the new steel puller helps to reduce maintenance costs still further. It consists of only five parts — there's only one spring and one plunger, and it's lubricated from the inside to prevent wear and to wash out dirt.

Four types available — There are four types of Cleveland Air Legs having conventional or telescopic, 3-ft., 4-ft., or 5-ft. feeds. Some models will take any 35-lb., 45-lb., or 55-lb. drill. Write for bulletin RD-30 that describes the Cleveland Air Leg in detail—the Air Leg that can help you get your rounds in faster for lower costs.

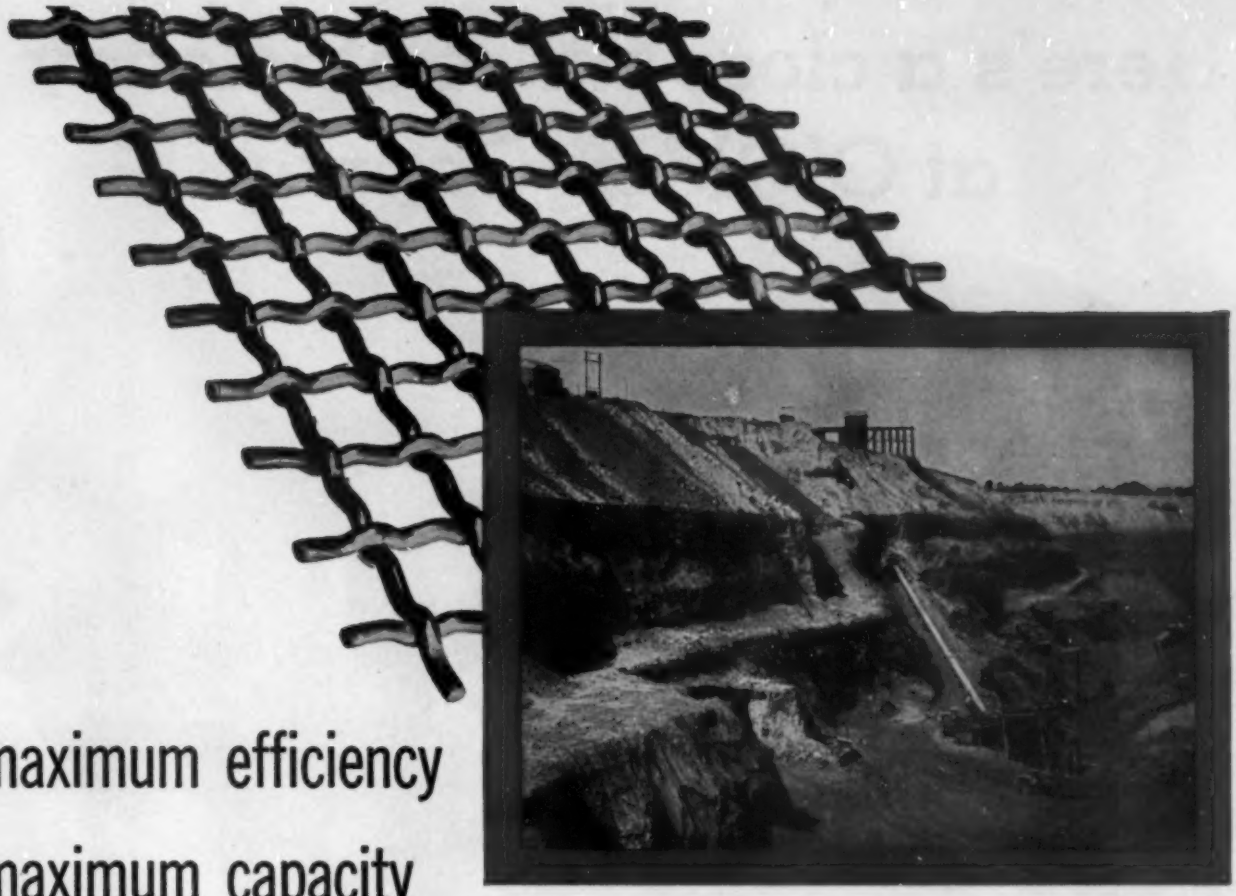
RD-65



Close-up view of new Cleveland Steel Puller. It consists of only 5 parts and has one spring and one plunger. Lubricated from the inside to assure easy operation and to flush out dirt, this new steel puller is also easy to assemble and disassemble.

CLEVELAND ROCK DRILL DIVISION
Westinghouse Air Brake Co.

12500 BEREA ROAD
CLEVELAND 11, OHIO



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maximum capacity

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You can always select the right screens with the correct mesh and metal for your job from CAL-WIC's extensive line of industrial screens. CAL-WIC Industrial Screens are fabricated in a wide range of types from the toughest carbon and alloy steels. Whether for processing, cleaning, grading, screening, for any type of equipment, CAL-WIC Industrial Screens will give the results you require.

CAL-WIC engineering assistance is available to help you solve your screening problems—write, today.

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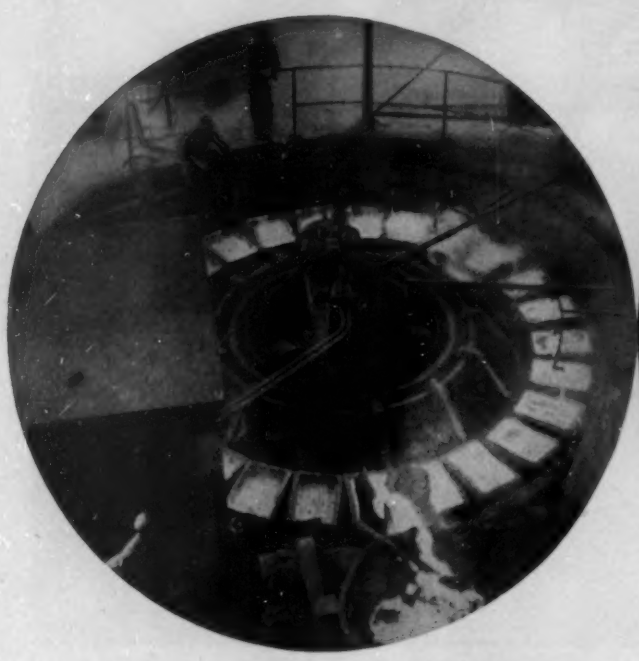
Here's a close-up of efficiency at O'Okiep Copper



TRAYLOR 22' CASTING WHEEL

TRAYLOR 10' x 20' COPPER CONVERTER

Both machines operating for 17 years

O'Okiep has been operating this Traylor machinery since 1938. Because of the efficient, dependable performance of their first Traylor converter, a second unit was installed 9 years later to expand production. In addition to the casting wheel and 2 converters, Traylor ladles and tilting devices are also used in the O'Okiep smelter.

Traylor has supplied many other leading copper and nickel producers with converters of the Pierce-Smith type in sizes up to 13' diameter by 35' length. Traylor casting machines are supplied in 2 types . . . straight line or circular. Sizes up to 40' have been built. Like all Traylor machinery, both converters and casting wheels are "Traylor-made" for their job, thus assuring peak operating efficiency and economy.

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CABLE AND MINE EXPERIENCE enable Anaconda to design and build shovel cable that resists razor-sharp rocks, water, sun, heat, cold, and — most important — run-overs.

This cable was "built" in our mines to perform better in yours

If you were a cable manufacturer as well as a miner, you could use your mine experience to build cable better than others.

But since you aren't, it will pay you to buy your cable from Anaconda—who *is* both cable manufacturer *and miner.*

FOR SHOVEL CABLE

Years of mine experience . . . of cable testing and improving . . . have taught us how to make a cable that *stays on the job longer under all conditions.* It's Securityflex* Type SH-D cable.

New, job-tested, high-grade butyl insulation assures better resistance to heat, water and compression. And new neoprene jacket makes this cable even tougher and more abrasion-resistant.

For Type SH-D, *or other shovel cable,* let Anaconda mine and cable experience pay off for you. See your Anaconda Distributor. Anaconda Wire & Cable Company, 25 Broadway, New York 4, N. Y. 88821

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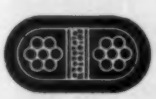
MINE CABLE

FLAT-TWIN CABLE



Improved stranding, new insulation, new grounding wire, and neoprene jacket make this a superior cable for shuttle cars, continuous miners, loaders, drill trucks, cutters.

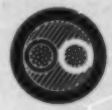
POWER CABLES

AnacondA Types W & G are rugged, sturdy and long-lived. Used for mine power, shovels, continuous miners, loaders, drill trucks, cutters.

SHOVEL AND DRILL CABLES

Securityflex* Types W and G are used with small shovels, self-propelled drill trucks, pumps and a-c mining equipment. For higher voltages, Type SH cables (shielded) are recommended.

SECURITYFLEX CORDS



Unexcelled for strength, wear resistance and long life. Type SO (heavy-duty) provides superior service on remote control and hand drills.

TROLLEY WIRE

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TELEPHONE WIRE

SHOT-FIRE CORD

WELDING CABLE

BOOKS

Electrical Equipment in Mines, edited by H. Cotton, *Transatlantic Arts Inc.*, $12.00, 456 pp., 1955.— A survey of the latest techniques and equipment written by specialists. Detailed information for both mining and electrical engineers is given on power supply, switchgear, cables, air compressors, coal cutters, conveyors, pumps, fans, and winders. Open pit equipment is fully dealt with, as are lighting systems, haulage, and signaling. Treatment is based on British practice.

The Uranium Prospector's Guide, by Thomas J. Ballard and Quentin E. Conklin, *Harper & Bros.*, $3.50, 251 pp., 1955.—Basic information for the prospector, miner, or layman. The mineralogy of uranium and uranium deposits is sufficiently complete to interest the technician as well as the prospector. Testing, sampling, and assaying are thoroughly discussed. Also explained are claim staking and mining law, development of uranium ore deposits, marketing the ore, and cost accounting records—important for tax purposes and development allowances on uranium ore. Bibliography. Tables, line drawings, and photographs.

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Lake Superior Milling Practice, A Technical History of a Century of Copper Milling, by C. Harry Benedict, *Michigan College of Mining & Technology Press,* $3.00, 151 pp., 1955.—The author of *Red Metal* details the technical advances in copper production, shows how milling problems were met and solved, and how science replaced trial-and-error methods. Beginning with the treatment of mass copper, Mr. Benedict follows the development of the steam stamp, fine grinding processes, reclamation, flotation, and leaching. This authoritative work includes 13 flowsheets and 14 illustrations of significant Lake Superior mills and machinery.

Geoloska Bibliografija Jugoslavije, by Sreten P. Milojević, *Institute Bibliographique de la Yougoslavie,* Belgrade, $3.00, 477 pp., 1952.—A comprehensive and extensive bibliography of the geology of Yugoslavia from the 14th century to 1944. Some 500 periodicals and serial publications are listed as sources. Titles of articles are given in the original language.

General Principles of Geology, by J. F. Kirkaldy, *Philosophical Library Inc.*, $6.00, 327 pp., 1955.—A university geology teacher for more than 20 years, the author is now head of the geology dept., Queen Mary College, London. The emphasis is on the main principles of geological science, which are the same whether applied to obviously economic or purely academic needs. The book is intended as a general introduction and also as a starting point for specialized work on more limited aspects.

Manganese, Metallurgy of the Rarer Metals, No. 3, by A. H. Sully, *Academic Press Inc.*, $6.50, 305 pp., 1955. —This book is the third of a series, each written by an authority. The first two volumes covered chromium and zirconium. Subsequent volumes will cover titanium, molybdenum, platinum and the metals allied with it, and uranium. The aim of the series is not only to provide a textbook, but also a readable work on the background and the metallurgical, chemical, and physical data of the metal concerned.

Turboblowers, Theory, Design and Application of Centrifugal and Axial Flow Compressors and Fans, by A. J. Stepanoff, *John Wiley & Sons Inc.*, $8.00, 377 pp., 1955—This book deals with the hydrodynamic and thermodynamic aspects of the turboblower design. It outlines new methods of attack on turbomachine problems and discusses the art of building turbocompressors in the U. S. and abroad. European designs occupy a prominent part of the book.

Please Order Publications on this Page from the Publishers

Let's Go Prospecting! by Edward Arthur, *Edward Arthur,* Suite 808, 1151 S. Broadway, Los Angeles 15, Calif., $3.50, 62 pp., 1954.—An introduction for the potential week-end prospector "to the fascinating study of mineralogy." Given are a summary of prospecting methods, uses, and marketing data of industrial minerals and metals likely to be found in California. Forty-six minerals are covered. Information is given on prospecting with ultraviolet light and prospecting for uranium and rare earth minerals. Illustrated with drawings, photographs, tables, and maps.

Mines Register, Successor to Mines Handbook, 1955-56 Edition, $25.00. This reference is expected to be published late in 1955. It will contain detailed reports on 5000 mines, corporate names and locations of 22,000 mines, production statistics, earnings reports, mining officers and directors, metal industry statistics, and mining and consulting engineers. Reservations for this book should be sent to Mines Register, 425 W. 25th St., New York 1, N. Y. *Copies printed will be limited to actual orders received.*

Symposium on Coal Sampling, *American Society for Testing Materials,* 1916 Race St., Philadelphia 3, Pa., $2.75, 152 pp., 1955.—Papers and discussions presented at the 2nd and 5th sessions of the ASTM 1954 annual meeting. The authors represent both companies utilizing coal and organizations studying the statistical problems of coal sampling in the U. S. and abroad. A series of experiments, costing approximately $50,000, were undertaken to collect data.

Practical Guide for Prospectors and Small-Mine Operators in Montana, by Koehler S. Stout, *Montana Bureau of Mines & Geology,* Montana School of Mines, Butte, Mont., $1.00, 124 pp., 1955.—Pocket-size booklet containing useful suggestions on prospecting, sampling and estimating, development and mining methods as well as on placer mining. Appendices include Montana's mining laws, definitions, and measurement units. Illustrated with diagrams, plates, and photographs. Also valuable for engineers illustrating mining methods to laymen and in training crews.

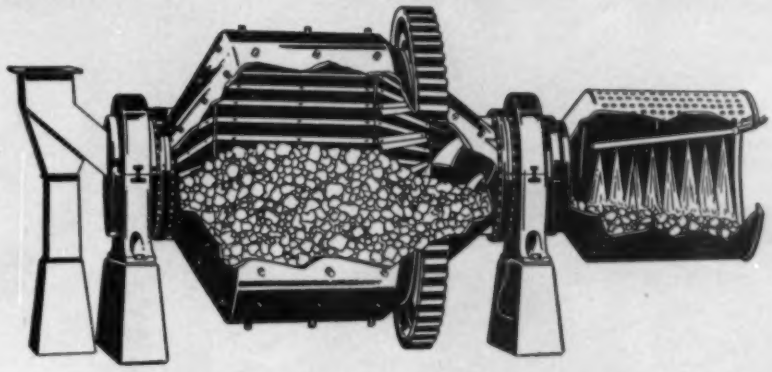
Statistical Summary of the Mineral Industry, Production, Exports and Imports, 1948-1953, prepared by the Mineral Resources Div., Colonial Geological Surveys, *H. M. Stationery Office,* Kingsway, London, England, approximately $4.00, 356 pp., 1955.—An annual volume of statistical tables that contains comprehensive details of the production, exports, and imports of all important commercial minerals and metals used throughout the world.

Geologic Section of the Black Range at Kingston, New Mexico, by Frederick J. Kuellmer, Bulletin 33, *State Bureau of Mines & Mineral Resources, New Mexico Institute of Mining & Technology,* Campus Station, Socorro, N. M., $2.00, 100 pp., 1954.—Structure and stratigraphy, detailed petrology of igneous rocks, and general guides to ore exploration. Well-illustrated.

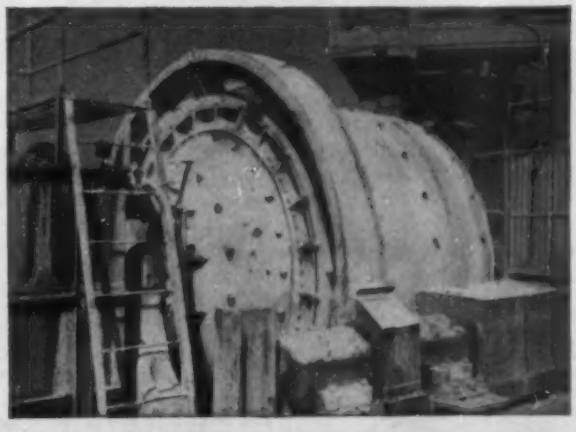
Consulting Services, *Assn. of Consulting Chemists & Chemical Engineers Inc.,* 50 E. 41st St., New York 17, N. Y., $1.00, 15th ed., 144 pp., 1955.—Now in a new 6x9-in. format, this reference lists members by more than 200 fields, by qualifications and activities, and by geographical locations, domestic and foreign.

Mining Year Book 1954, compiled by Walter E. Skinner, *Walter E. Skinner,* 20, Copthall Ave., London, E. C. 2, England, $7.00 postfree, 864 pp., May 1955.—Complete and up-to-date information on 968 mining companies operating in all parts of the world. Particulars include directors, dates of incorporation, description of property, plant erected or in course of erection, capital, dividends, and financial position. Addresses are given for 1168 mining engineers and managers and the companies with which they are connected.

HARDINGE SCRUBBERS FOR PIT-RUN MATERIALS



Large diameter, short length trunnions permit chute feeding of unsized ore and rock at rates up to 600 tons per hour.
The mass loading and ball-mill action in the scrubber quickly and completely slurries the clay and dirt, permitting ready separation on washing screens or trommels.



View of a 10' x 66" Hardinge Scrubber cleaning crushed dolomite in a California plant.

BULLETIN 37-A-2

HARDINGE
COMPANY, INCORPORATED

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Multiple Molded Rubber Block Cyclones Make Sharp Separations in 10 - 20 Micron Range . . .

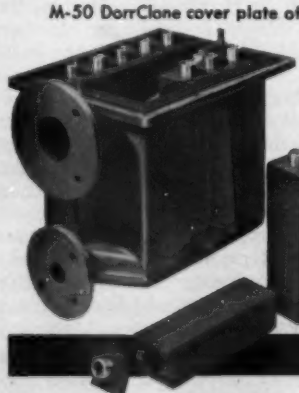
Latest advance in wet cyclone design is the Type M DorrClone . . . developed for size separations in the 10 to 20 micron range. Designated as M-30 and M-50, this new design is now available with twenty 30 mm dia. rubber block cyclones or ten 50 mm cyclones in a common housing. Housings may be either cast stainless steel or bronze construction. When cover plate is bolted in place, each block is under compression to form a tight seal between feed, overflow and underflow chambers.

As with all cyclones, capacity and mesh of separation in the M DorrClone varies with the diameter of the individual units, operating pressure, feed solids concentration and specific gravity of the solids. On a slurry with a solids specific gravity of 2.7, the M-30 separates at 8-10 microns and the M-50 at 15-20 microns. As to capacity, the M-30 handles approximately 70 gpm at 20 psi, 100 gpm at 40 psi and 125 gpm at 60 psi. At these pressures the M-50 handles approximately 100 gpm, 140 gpm and 170 gpm. Top operating pressure for both is 125 psi.

For more information on this newest classification tool write for a copy of Bulletin No. 2504. Dorr-Oliver Inc., Stamford, Connecticut.

M-30 DorrClone completely assembled.

M-50 DorrClone cover plate off.



Lab units also available . . . for test units or very low flows. Fabricate stainless steel housing contains four 30 mm units or two 50 mm units. Separations are the same with equal diameter cyclones. Write for quotation.

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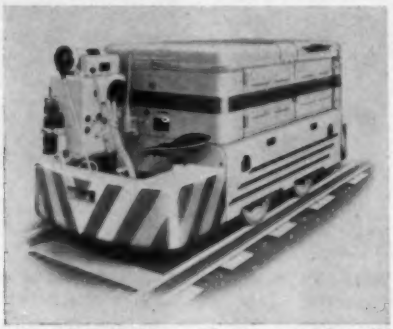
Mine-O-Motive

The Plymouth Mine-O-Motive line of mines locomotives from the *Plymouth Locomotive Works*, division of Fate-Root-Heath Co., is offered in



sizes from 5 to 10 tons and will eventually include a 2-ton trammer. Suitable scrubber and exhaust conditioners are offered on all models along with diesel-torque converter drive. **Circle No. 1**

Scraper

Euclid Div. of General Motors has the latest addition to its line of motor scrapers, model S-7, in produc-

tion. Euclid's first overhung engine scraper to go into production, it is powered with a 143-hp diesel with 5-speed transmission. **Circle No. 2**

Mobile Testing Lab

Denver Mobile Ore Testing Laboratory is a compact unit that provides facilities for sampling, testing,

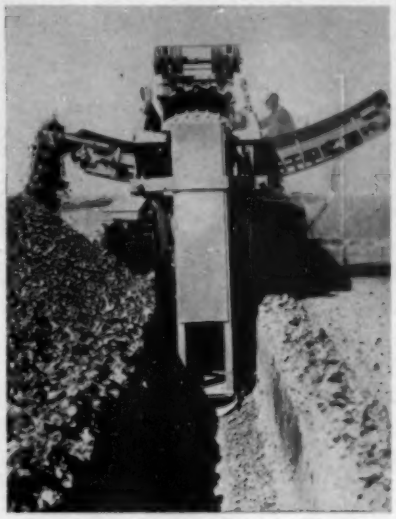
and development of mill flowsheets for tailing dumps, or new deposits. *Denver Eqpt. Co.* recommends unit for governmental exploration programs or for companies with widespread holdings. **Circle No. 3**

Lightweight Diesel

Cummins Engine Co. has a lightweight, 175-hp Turbodiesel designated the JT-6. This is a 6-cyl, inline type with 4⅛-in. bore, 5-in. stroke, and displacement of 401 cu in. Installed in a truck the JT-6 weighs only 1615 lb, or 9.2 per hp. **Circle No. 4**

Ditcher

Gar Wood Industries Inc. announces a pipeline and utility ditcher, the Buckeye 308. This heavy duty, wheel-type ditcher was specially designed for digging cross-country



ditches and for city gas, water, oil, sewer, conduit, and cable lines. It digs to a maximum depth of 5 ft 6 in. with optional width of cut varying from 16 to 32-in. increments. **Circle No. 5**

Pneumatractor

Schramm Inc. offers a low priced self-propelled air compressor called the Standard Pneumatractor. The same 125-cfm engine compressor power plant used in the Heavy Pneumatractor and in the 125-cfm Pneumapower portable compressor is used. Only tractor features have been modified. Price is about $3675.00 **Circle No. 6**

Compressor

Ingersoll-Rand has added a 125-hp electric-driven air compressor to its line of air-cooled, two-stage type 40 stationary compressors. Some of the new features of the unit are: single-core, horizontal-flow intercooler, new shrouding, force-feed lubrication, full free-air unloading, and a new version of the I-R channel valve. **Circle No. 7**

Rotary Portable

Gardner-Denver Co. is marketing an all new rotary portable air compressor said to combine the basic rotary advantages of compactness, light weight, and simplicity with the weather-defying advantages of water cooling. The compressor has a capacity of 600 cfm and has been named the G-D Rotary 600. **Circle No. 8**

Transistorized Counters

Universal Atomics Corp. is featuring a line of geonuclear instruments including completely transistorized walking stick Geiger counter, a gun-type Geiger counter, the Miracle transistorized amplifier audio, and three scintillators: the model 117, the Deluxe model, and the Royal model. **Circle No. 9**

One Mast Fork Lift

Entirely new concept in lift trucks is being introduced with the *Hyster Co.'s* Monomast, a design consisting of one mast. According to the com-

pany, it boasts panoramic visibility never before possible. The Monomast engineering consists of two box-type sections, one telescoping within the other. **Circle No. 10**

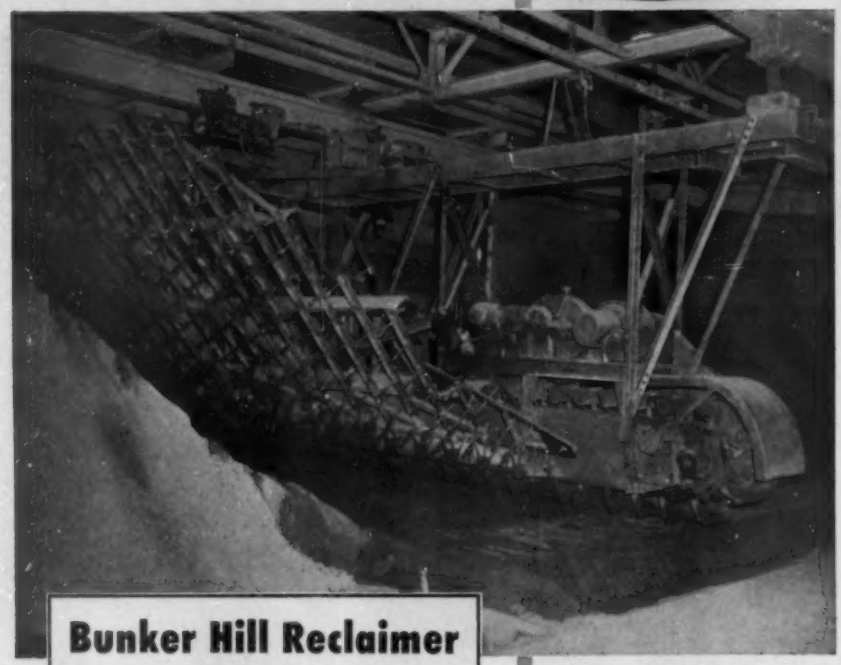
Versatile Rod

International Nickel Co. recently demonstrated Inco Rod "A", a multipurpose electrode capable of producing strong, ductile joints between a wide range of dissimilar alloys. The electrode is expected to give high quality welds on better than 90 pct of dissimilar welding jobs and thus reduce electrode inventories in the average plant. Now in full production, Inco-Rod "A" comes in 14-in.

(Continued on page 604)

A Better Reclaimer

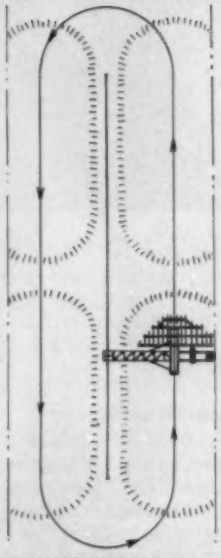
COSTS LESS
IMPROVES
PERFORMANCE



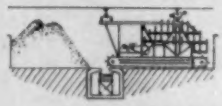
Bunker Hill Reclaimer

Achieves complete uniformity of preparation charge and is fully automatic. Operates to full capacity of subsequent flow sheet. Stearns-Roger engineered design saves weight for lower first cost. One machine serves any number of tandem bedded piles, each 30′ wide. The unit shown at Bunker Hill & Sullivan's Kellogg custom lead smelter has a rated capacity of 150 t.p.h. on minus ¼" material weighing 110-125 lbs. per cu. ft. with 2-10% moisture. This Reclaimer has operated as high as 200 t.p.h. for sustained periods. Over 15 months' initial operation is reported highly satisfactory.

These same features can cut costs for you. Write for complete data and price.



PLAN OF BEDDING PLANT



ELEVATION

Stearns-Roger

THE STEARNS-ROGER MFG. CO. DENVER COLORADO

DENVER, SALT LAKE CITY, HOUSTON, EL PASO
STEARNS-ROGER ENGINEERING COMPANY, LTD., CALGARY

lengths in diameters of 3/16, 5/32, and ⅛-in. There is also a 3/32-in. diam with a center grip. **Circle No. 11**

Big Scraper

Wooldridge scrapers with capacities up to 41 cu yd have been announced by the *Wooldridge Mfg. Div.*, Continental Copper & Steel Industries Inc. The units are open-

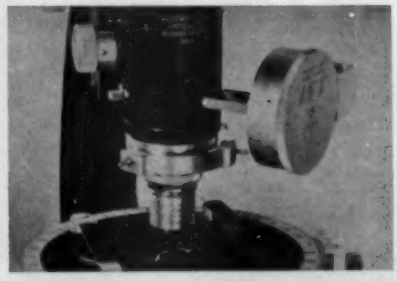
bowl, cable-operated types and are reported able to utilize the full horsepower of the largest tractors now built and the larger models announced for future production. **Circle No. 12**

Screening

Hewitt-Robins Inc. has developed a vibrating screen of revolutionary design for screening and sizing coal, ore, chemicals, and other bulk materials. The screen offers higher screening efficiency and operates on 50 to 75 pct less power than coventional vibrating screens. **Circle No. 13**

Geologist's Aid

A microscope accessory to aid identification of minerals and chemicals has been introduced by *Bausch & Lomb Optical Co.* Known as an accessory slot compensator, it will speed the identification process for



geologists and chemists. The first step in identifying a mineral is to measure "birefringence" with the compensator. Determination charts are then used to obtain readings. **Circle No. 14**

Electric Plants

Two series of Ford-powered electric generating plants announced by *D. W. Onan & Sons Inc.* offer unusual compactness and low operating costs, according to the manufacturer. Series 25EC with 6-cyl ohv engine has 25-kw capacity and the 35ED series with ohv V-8 Ford engine, 35-kw capacity. **Circle No. 15**

(21) AIR POWER DOOR: *American Mine Door Co.*, now celebrating its 50th anniversary, has introduced the Canton air power door for installations where the company's regular mechanically operated door is impractical. Space limitations, sloppy ground conditions, and corrosive mine water have dictated the development of this door, in which nothing is below the track surface except the frame sill.

(22) INDUSTRIAL PUMPS: Bulletin from *Nagle Pumps Inc.* points out that impeller design is not standardized, but available in four design types plus two-vane trash type to meet varying operating conditions. This makes these units suitable for difficult applications.

(23) PNEUMATIC CONVEYORS: Bulletin 105 from *Convair* lists materials handled by pneumatic conveying systems and illustrates the three types of conveyors available—vacuum, vacuum pressure, and pressure systems.

(24) FLOTATION: *Denver Eqpt. Co.'s* bulletin M4-B73 tells how 650 tpd of extremely complex lead, zinc, copper, and pyrite ore is milled by Denver Sub-A flotation at the Rammelsburg and Bollrich mills in Germany. Complete flowsheets and metallurgical data of each mill explain ore treatment.

(25) POWER UNITS: The 18 heavy duty engines in *International Harvester's* catalog have a range of 16.5 to 200 net hp, which means there is an engine for almost any specific power need. Given are full specifications for applications of these units to new installations or as replacements.

(26) HEAD PROTECTION: In coal or metal mining—in wet or dry mines, *Mine Safety Appliances Co.'s* Skullgards offer the right, light, strong, and durable head protection. Various types are illustrated in bulletin DK-14 as well as the MSA eyeshield that may be attached to any Skullgard already in use.

Free Literature

(27) MORE HP PER $: *Le Roi's* 8-page, 3-color bulletin E-9 on the L3000, H2000, and F1500 uses cutaway view and photographs to show advanced features such as modern valve-in-head design. Other features discussed include: full length guided valve stem mechanisms, lightweight cam ground aluminum pistons, and drop forged crankshafts with polished bearing surfaces.

(28) DIESEL ENEMY: Sulphur in fuel oil is a deadly enemy of your diesel engine. *Caterpillar Tractor Co.'s* "Let Your Diesel Live" tells the story of lubricating oils and shows how these oils affect the life span of your engine.

(29) NI-RESIST: *International Nickel Co.'s* bulletin A-71 features application of Ni-Resist, corrosion resistant nickel alloyed cast iron. The 64-page book tabulates mechanical and physical properties offered by the eight types of Ni-Resist. The section on corrosion data shows its superiority over gray cast iron under 400 different industrial conditions.

(30) ROCK DRILLING: *Ingersoll-Rand's* Drillmaster utilized three distinct methods of drilling. It has the Depth-Master "down the hole" drill for deep blastholes up to 6-in. diam, the Power-Master hammer drill for 4¼-in. holes, or the Roto-Master rotary drill for hole sizes up to 6¼ in.

(31) PROCESS ENGINEERING: Specialists in first-of-its-kind-plants since 1927, *Singmaster & Breyer* has a bulletin outlining services. Among the many photographs are: a nitrate plant in Iceland, a venturi fume scrubber for American Zinc Co., a zinc smelter in Japan, a metal working laboratory in Ottawa, Canada.

(32) SCRAPER: *Allis-Chalmers* now has a medium-sized, rubber tired pull scraper with an 8.4-cu yd struck and 11-cu yd heaped capacity. Model 108 is cable operated, with an overall length of 27 1/3 ft, overall width 10 1/3 ft, and in load-carrying position, a 7 2/3-ft height. Width of cut is 8½ ft, depth to 10 ft.

(33) TRACTOR SHOVELS: A 12-page catalog from *Clark Equipment Co.'s* Construction Machinery Div. shows design, construction, operation, and correct application of 1-cu yd capacity Michigan "75" tractor shovels. Models include all-wheel, front-wheel, and rear-wheel drive.

(34) CLASSIFICATION UNIT: "The FR DorrClone" from *Dorr-Oliver Inc.* tells the historical development, physical characteristics, capacities, and ranges of separation of this newly designed classification unit. Operating results from three commercial installations, line drawings, and photographs of typical units are also given.

(35) MATERIALS HANDLING: *Hyster Co.'s* field report 54 illustrates up-to-date handling of heavy loads of stone in a southern granite quarry with the QN-20 lift truck. This is an actual case history of the use of Hyster equipment in "one of the most rugged material handling operations in the nation."

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Oct. 15, 1955—if mailed in U. S. or Canada

Please send me { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
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51	52	53	54	55	56	57	58	59	60
61	62	63	Students should write direct to manufacturer.						

Name_____ Title_____

Company_____

Street_____

City and Zone_____ State_____

(36) FOR OIL & U: *Radiac Co.* has a bulletin on the deep drillhole Scintilogger, designed for radioactivity logging of drillholes to 6000 ft. Its verified in-hole-out-hole radiation profiles indicate deeply buried uranium deposits and are said to identify oil productive zones in both new wells and in new productive zones of old wells.

(37) VIBRATORS: Catalog 11 from *Cleveland Vibrator Co.* gives specifications, prices, and covers Cleveland's silent, eccentric weight vibrators, and electro-magnetic vibrators. Information is also furnished for vibrating tables and pneumatic vibrators.

(38) METAL-CLAD SWITCHGEAR: Bulletin GEA-5664C from *General Electric* contains detailed discussions and advanced design features of metal-clad switchgear rated 2.4 to 13.8 kv and 50 to 500 mva.

(39) WELDING: *Metal & Thermit Corp.* has a series of catalogs on the entire line of Murex electrodes for arc welding as well as rods and wire for gas, submerged arc and inert arc. Full information includes physical properties and chemical analyses.

(40) V-SCREEN: Bulletin 243 from *Nordberg Mfg. Co.* describes the Symons V-screen, specifically designed for fine screening, sizing, dewatering, dedusting, cleaning, and washing. Symons V-screen multiplies its screening effect by combining centrifugal and gravitational forces for high capacity and sharp, single cut, wet or dry separations.

(41) VERSATILE SKID-SHOVEL: *Drott Mfg. Corp.* has a catalog on the International Drott four-in-one skid-shovel. Whether the unit is moving or standing still, the operator merely by placing the "shovel selector" in the desired position can convert the machine into a bull-clam shovel, bulldozer, skid-shovel or a clamshell.

(42) PIPING INSTALLATION: "True Piping Economy" from *A. M. Byers Co.* compares wrought iron and other types of pipe in terms of the three important costs to consider in buying pipe: initial purchase cost, cost of installation, and cost of maintenance.

(43) WELDING & CUTTING: *Air Reduction Sales Co.* has a new publications list. Briefly noted in this 16-page booklet are more than 100 welding and cutting technical reprints, text books, safety booklets, and slidefilms.

(44) FEEDERS & SIZERS: *Pulva Corp.* has a revised catalog on Pulva-Sizers and Com-Bin feeders. All sections have been expanded and that covering the Com-Bin feeder includes additional surge capacity and dimensional data for all sizes from ½ to 857-cu ft capacity.

(45) ROOF BOLTING: A *Republic Steel Corp.* booklet tells how Republic's mine roof bolts provide safe, economical, and efficient roof bolting. Explained are six major advantages of Republic's forged steel wedge nut and forged steel rigid shell assembly.

(46) TUNGSTEN: *Sylvania Electric Products Inc.*, Tungsten & Chemical Div., has an excellent booklet on tungsten illustrating the steps from ore to finished products. Also given are physical properties, conversion factors, and a resistance-temperature chart.

(47) MOLYBDENUM: *Sylvania Electric Products* also has an equally excellent book on molybdenum, in format like the one above on tungsten.

(48) TWIN CRAWLER: Specifications, drawings, and on-the-job photographs in form 601 from *Euclid Div.* of General Motors present the Euclid TC-12. With two engines providing a total of 388 hp and separate Torqmatic drives for each crawler track, "the TC-12 has no equal for smooth performance, ease of operation, and workability."

(49) ROOF-BOLTING STOPER: Bulletin RD32 from *Cleveland Rock Drill Div.* introduces the S20 Vac-Nu-Matic stoper that together with its Drift-Nu-Matic feed "represents the first basic change and improvement since the self-rotator." Features include: new type drill steel, new dust collection system, short overall height—operates easily in 26-in. coal, speed in roof-bolt drilling, and reduction in steel changes.

(50) SURFACE TENSION TESTING: *Pollack Products Co.'s* bulletin 2 illustrates uses of the new pocket-size Jiffy Loop surface tension tester. This device provides a simple, quick-test method for taking accurate surface tension measurements under production conditions.

(51) MINERAL DRESSING: Latest issue of "Mineral Dressing Notes" from *American Cyanamid Co.* contains "Handling and Feeding of Aero Brand Cyanide." This 16-page paper is illustrated with drawings and photographs.

(52) DIAMOND DRILL BITS: *Diamond Tool Research Co.'s* catalog lists six reasons for using DT diamond drill bits: competitive pricing, skillful selecting and mounting, right matrix for the job, individualized resetting, made by diamond specialists, fast delivery on new bits and resets.

(53) SMELTERS: *Mace Co.'s* 28-page booklet on smelters points out the principal variations from the old type blast furnace. These are: diametrically opposed rectangular tuyeres in place of circular tuyeres at regular intervals, adjustable tuyeres for regulating oxygen supply to smelting zone, removable crucible, an arrangement for keeping the crucible hot. Capacity of furnaces ranges from 5 to 250 tpd of charge.

(54) TRACTOR-EXCAVATOR: *Eimco Corp.* built and designed the Eimco 105 tractor-excavator to fill the need for a machine heavy and strong enough to take the extra loads imposed by attachments. Bulletin L1033 opens to a single large sheet, showing a cutaway view of the 105, with 27 features listed and cost saving advantages noted.

(55) TUNNEL BORING: Catalog G-110 from *Goodman Mfg. Co.* features custom-built tunnel boring machines for tunneling without the use of explosives. The development of these machines is traced and photographs show equipment used at Oahe dam.

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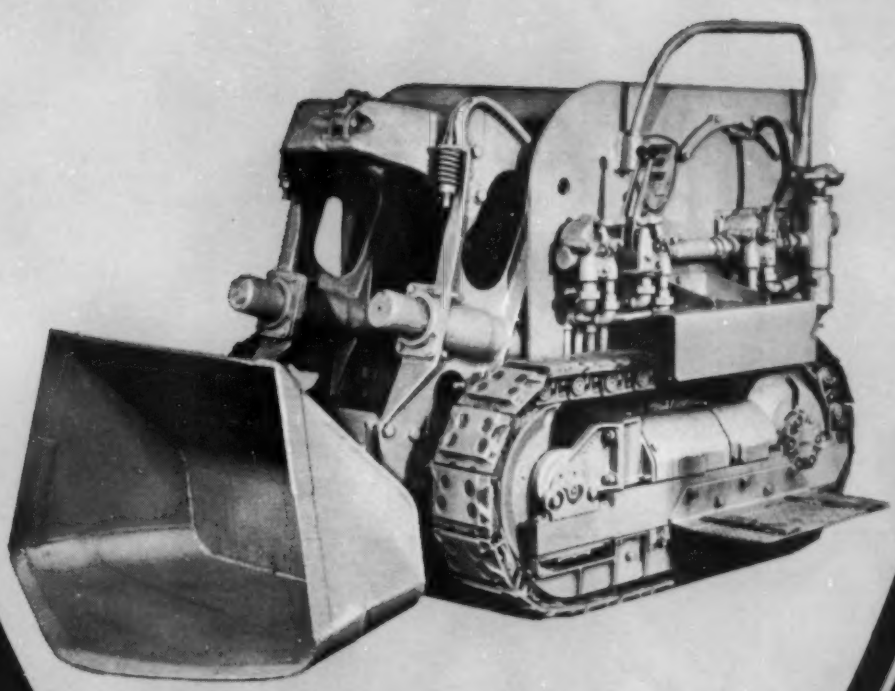
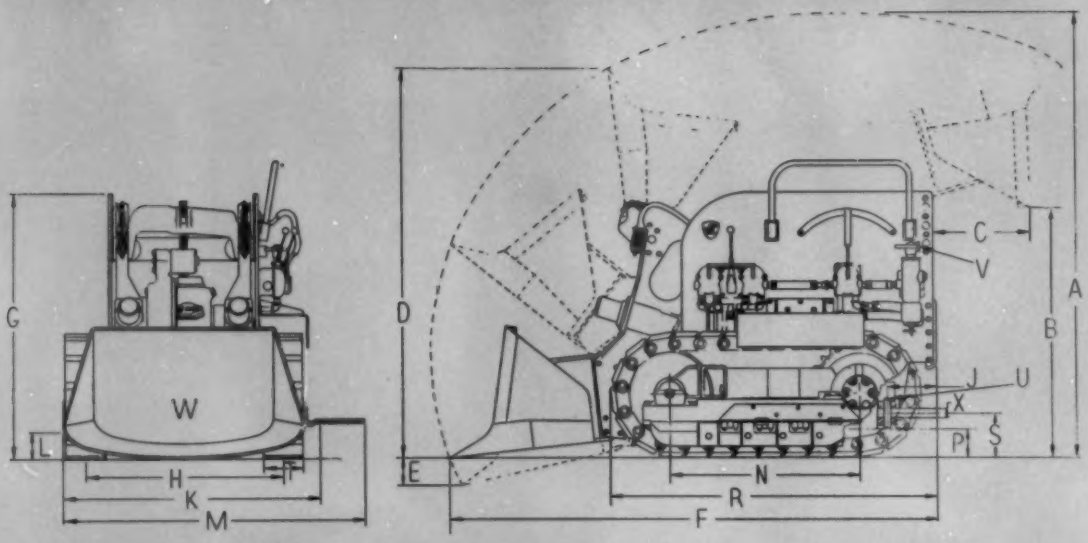


MODEL 630

EIMCO MODEL 630 SPECIFICATIONS



		FEET	MM
A.	Head Room Std. Bucket	7'10"—9'5½"	2390—2885
	Head Room Nested Bucket	6'8" —8'8"	2030—2640
B.	Discharge Height Std. Bucket	4'4" —6'2"	1320—1880
	Discharge Height Nested Bucket	3'8"—5'10"	1120—1780
C.	Discharge Distance Std. Bucket	19"—22"	480—560
	Discharge Distance Nested Bucket	12"	305
D.	Height at Minimum Length (Std. Bucket)	7'3"	2210
E.	Digging Depth Below Grade	8½"	215
F.	Overall Length (Bucket Down — Std. Bucket)	9'4"	2845
G.	Minimum Height	4'11½"	1510
H.	Track Gauge	45"	1145
J.	Distance from Drawbar to Rear of Machine	11⅛"	285
K.	Minimum Overall Width	4'10½"	1490
L.	Oscillation at Center Line of Front Idler	6"	150
M.	Overall Operating Width	5'8¼"	1745

		FEET	MM
N.	Length of Track on Ground	43⅞"	1115
P.	Ground Clearance	6"	150
R.	Minimum Length	6'3⅛"	1910
S.	Height of Drawbar Above Ground	9⅝"	245
T.	Track Shoe Width	9"	230
U.	Drawbar Pin	1½" dia.	38
V.	Air Inlet — Pipe Size	1½" IPS	
W.	Bucket Capacity	5½—11 cu. ft.	⅙—⅓ cu. M.
X.	Drawbar Tongue Opening	2"	50
	Weight Complete	9400 lbs.	4260 Kg.
	Area of Ground Contact	790 sq. in.	5,100 sq. cm.
	Speed	0—1.5 m.p.h.	0—2.4 Km/hr.
Y.	Motors (Eimco Air or Electric)	3	3
	Electric Motor Rating	Special	
	Air Motor Rating	12 HP @ 90 p.s.i.	
	Drawbar Pull (lbs.) at Zero Track Slippage	10,600 lbs.	4,800 Kg.

Eimco's 630 series, air or electric powered crawler loader is the answer to a need expressed by miner and contractor alike.

The 630 has many advantages in design for the loader user. Independent track control provides a pivoted turn by running one track forward and the other reverse. This feature makes it possible to attack the muck pile from any angle without backing to make a new run. Improved rocker-arm design provides better action and longer life. All wearing parts are easily replaceable in new patented design. All parts easily accessible. Tracks oscillate for uneven ground. Tracks are equipped with spring release to clear rocks or obstructions in the tracks. Heavy shafts and oversized anti-friction bearings are used throughout. All parts are of heavy alloy-steel cast or fabricated construction for typical Eimco long-life heavy duty operation. Loading capacity 2-3 tons per minute.

Write for complete information.

THE EIMCO CORPORATION

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B-115

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CRUSHER

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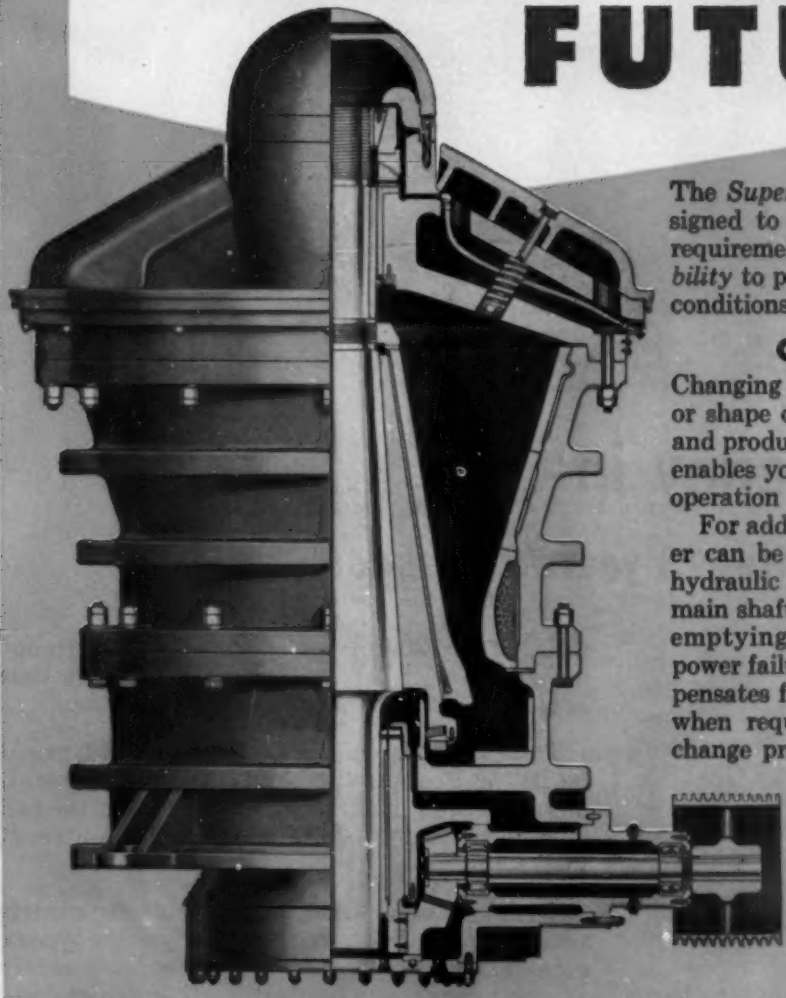

The *Superior* crusher you install today is designed to meet your specific and immediate requirements — and it also has *built-in flexibility* to permit adaptation to future operating conditions.

Complete Adaptability

Changing the eccentric throw, crusher speed or shape of crushing chamber, varies capacity and product size. This high degree of flexibility enables you to obtain the best possible crusher operation to suit other plant equipment.

For additional flexibility, the *Superior* crusher can be fitted with *Hydroset* mechanism, a hydraulic arrangement for raising or lowering main shaft and mantle. This control facilitates emptying the crushing chamber in case of power failure or other emergencies. It also compensates for wear on concave and mantle and, when required, makes it possible for you to change product size instantly.

Write for Bulletin 07B7870

This 32-page bulletin describes the *Superior* crusher and gives you valuable crushing data. It's a book you'll want to have and keep. Ask your A-C representative for a copy or write Allis-Chalmers, Milwaukee 1, Wis.

A-4655

Superior and *Hydroset* are Allis-Chalmers trademarks.

ALLIS-CHALMERS

400-Car repeat order in 1954 tells better than any other words how the user's original 340 cars performed since 1941. All 740 cars, bought from ACF Industries, Inc., were built of COR-TEN Steel, a high strength, low alloy steel containing nickel.

Put your money in cars like these

...still good after 13 years' continuous use

THE FOLLOWING EXAMPLE is typical:

A West Virginia mining company bought 340 mine cars built of high strength, low alloy steel containing nickel . . . produced by United States Steel Corporation under the trade name of COR-TEN steel. After 13 years of resisting corrosion and battering, these 5-ton cars still remained in good operating condition.

Impressed by this performance, the mining company ordered 400 more cars last year. Naturally, COR-TEN steel was again specified.

High strength, low alloy steels of this type have a 50% higher yield point than does structural carbon steel. Plus definitely greater resistance to impact, wear, fatigue and abrasion. Moreover, the nickel steels retain much of their original strength during years of use, because they offer five times as much resistance to atmospheric corrosion.

This means not only less maintenance, but greatly increased life for equipment made of high strength, low alloy steels containing nickel. So get all the facts . . . send for a copy of "Nickel-Copper High-Strength Low Alloy Steels."

It tells you why these nickel steels offer superior resistance to atmospheric and many other types of corrosion . . . how they act in sub-zero temperatures . . . their response to fabrication. It describes design factors that can help you cut deadweight. Write for your copy now and learn how these steels can save you money.

INCO TRADE MARK **THE INTERNATIONAL NICKEL COMPANY, INC.** 67 Wall Street New York 5, N.Y.

Texas City Smelter Survives

The Texas City tin smelter will stay in business until at least June 30, 1956, as a result of House passage of the bill extending the facility's life. The bill passed the lower Chamber by unanimous consent as it did in the Senate. It is estimated that smelter operation will cost the U. S. about $50 million for the year, the same amount expended this year. Recommendations for passage were based on national defense. White House approval is not needed for the bill to become effective.

Minerals Mobilization Office

Tentative plans are ready for an Office of Minerals Mobilization in the Dept. of the Interior. The operation will start as soon as funds for fiscal year 1956 are appropriated. OMM will have three functions: to develop and maintain current projections of domestic production capacity and of imports under partial or full mobilization; to recommend programs for minerals likely to be in adequate supply; and to develop plans assuring supply in the event of full or partial mobilization or attack.

Production Line Grubstaking

Out of Anchorage, Alaska, comes word that Grubstakers Inc. has been formed. It's another group formed to help prospectors get the cash needed to go out in the field. Financing is in return for a share of anything the prospector finds, usually on a fifty-fifty basis, in the traditional manner. Interested prospectors may contact James E. Rigsby, Box 1818, Anchorage. The Territorial Dept. of Mines reports a tremendous increase in the number of uranium prospectors in the Third and Fourth Divisions.

National Gypsum Builds in New Jersey

National Gypsum Co. plans to build a gypsum wallboard and plaster plant in Burlington County, N. J. The plant should be in production within a year, according to the company. The plant, the 38th in the National Gypsum chain, will employ upwards of 400 workers and have an annual payroll of more than $1 million. Gypsum building products are in short supply throughout the country. National Gypsum is developing the largest gypsum deposits in North America near Halifax, N. S.

Plateau Prospecting Has Seasonal Surge

Warm weather is bringing the hopefuls to the Colorado Plateau in droves in the search for uranium, according to the New Mexico Mining Assn. However, some observers feel that most of the surface ore showings have already been filed. It's now expected that valuable deposits will have to be located by drilling and shaft sinking.

Coal Power for Aluminum Projects

Among entries for another round of aluminum production increases are "embryonic" plans by St. Joseph Lead Co. and Pittsburgh Consolidation Coal Co. for 66,000-ton per year, $85-million aluminum plant. Coal would be power source. Olin-Mathieson Chemical Corp. has requested assistance from ODM for building a 60,000-ton, $74-million primary aluminum producer in West Virginia, also to be coal powered.

Now you can drill 6¾ to 9-in. blast holes

fast and economically—

BUCYRUS ERIE

40-R ROTARY

The new 40-R is another significant Bucyrus-Erie advance in rotary blast hole drills. Flexible and powerful, it puts down medium-large holes quickly and efficiently in both hard and soft formations.

Continuous progress in any material is assured by this exclusive combination of features: *variable drilling speed* through Ward Leonard electric control and *variable down pressure* through hydraulic motor control.

The Ward Leonard variable-voltage system gives the operator smooth, instant command over rotation of the drill pipe. He can choose the most efficient speed for a given formation — can vary the speed as required without stopping the drilling operation. In hard formations maximum down pressure may be exerted on the bit while the drill pipe is turning slowly. In soft material, rotating speed can be increased substantially as down pressure is automatically reduced.

There are many other features that contribute to low operating costs and long machine life. Write today for full details and specifications on the 40-R, available with either diesel-electric or full electric power. 1885SC

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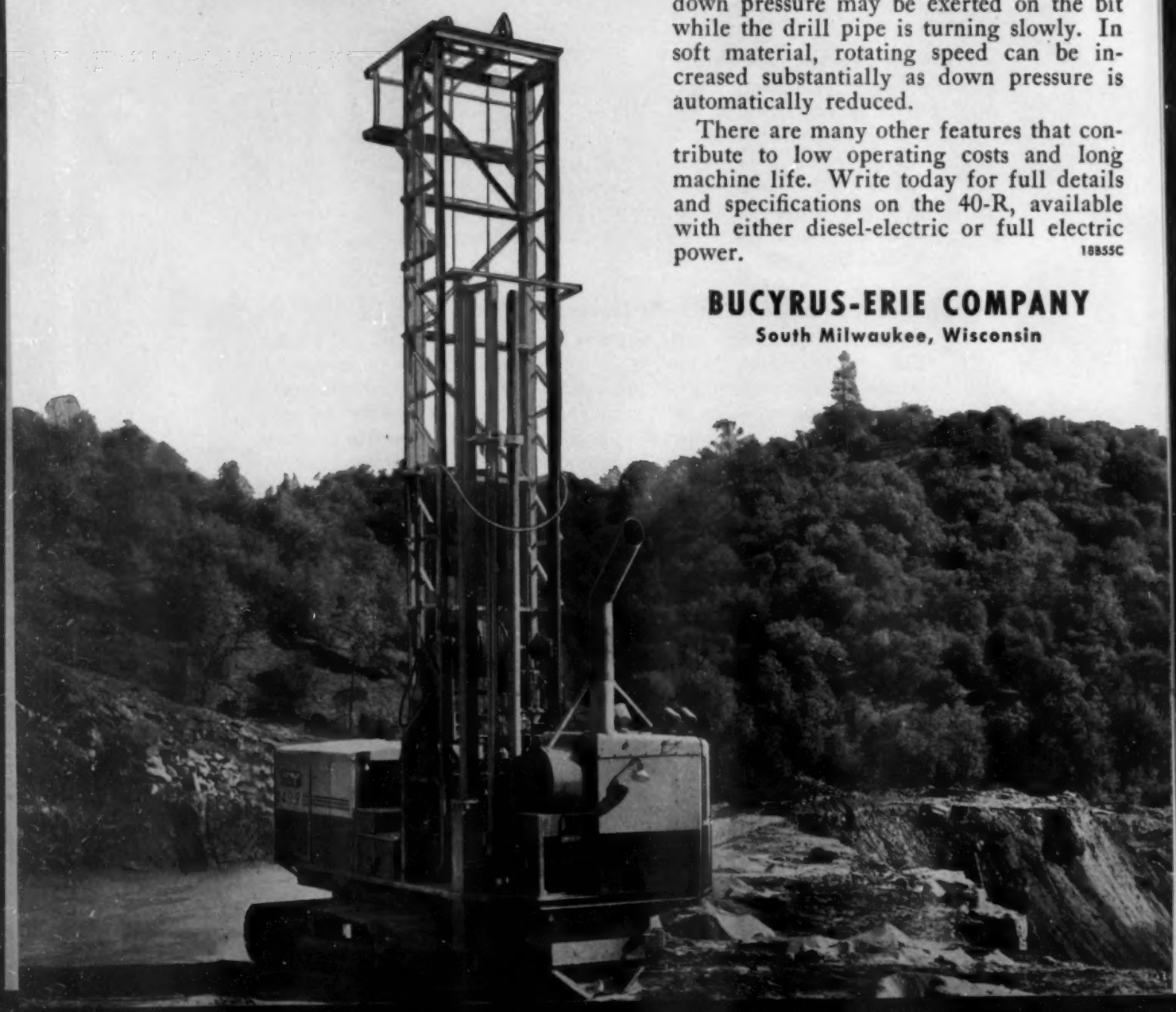
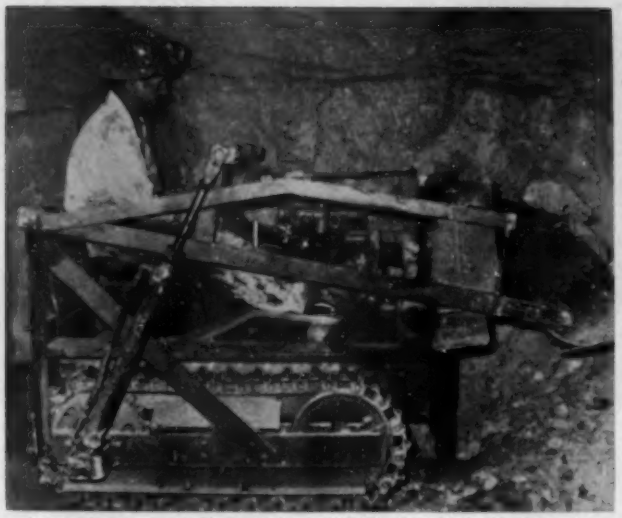
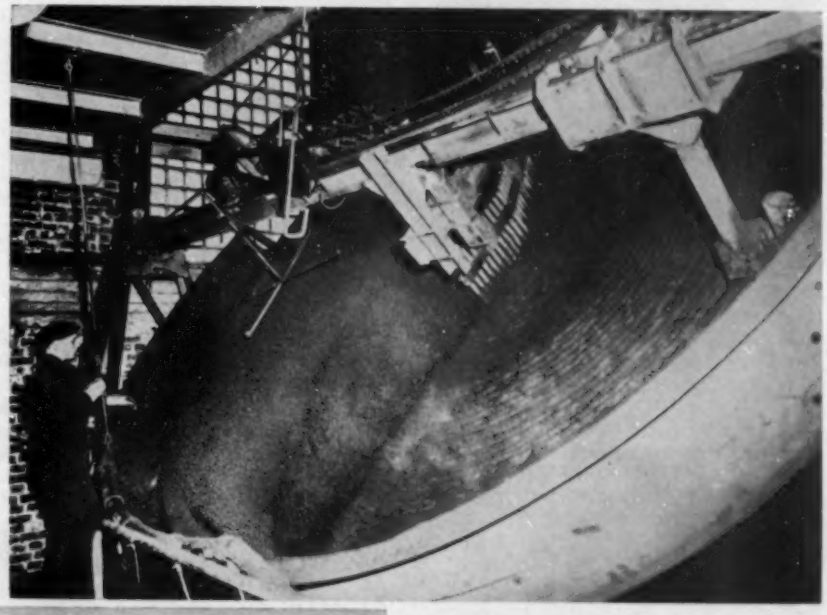


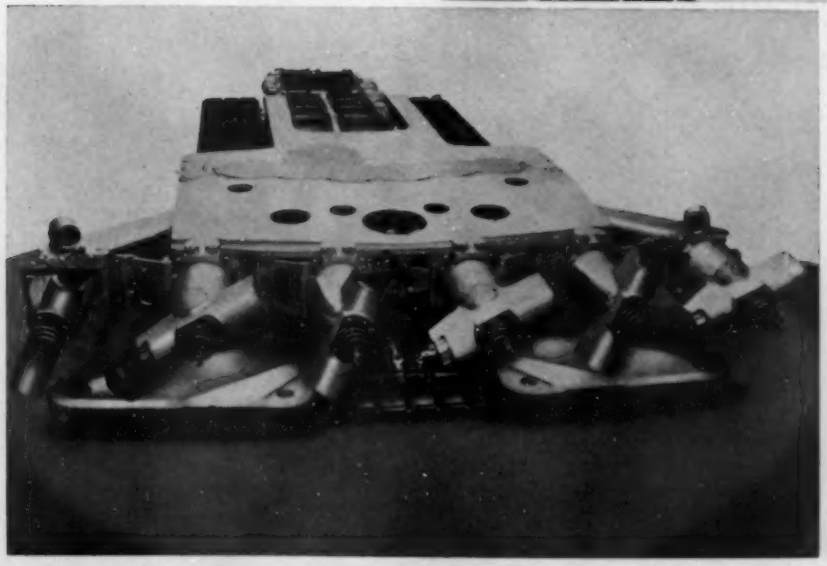


A new low-cost mucking machine, Model FD Diesel, has been developed by Earl H. Pence & Co. Inc.

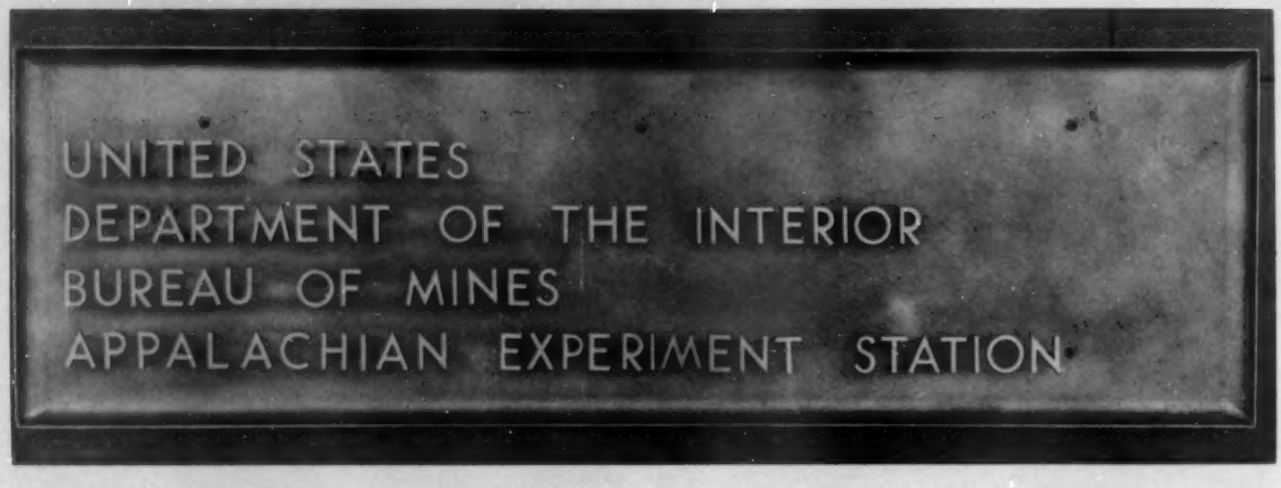
This International TD-24, with 161 drawbar hp, is cutting away at some 3 ft of overburden at a strip coal mine near Wartburg, Tenn.



Dravo Corp. has supplied International Nickel Co. with the first commercial disk for pelletizing iron ore in North America. The disk was developed four years ago by Lurgi, Germany's largest designer and manufacturer of sintering and pelletizing equipment. This Lurgi pelletizing disk is one of several in operation abroad.



The Cleveland Rock Drill Div. of Westinghouse Air Brake Co. is about to put its BCR Hydra-Miner through extensive tests in producing mines. Late last year an operating test model was developed to advance specifications and tested in the firm's experimental coal mine and in the shop.



Morgantown Unit Becomes a Reality

Probably one of the most significant facts in the establishment of the U. S. Bureau of Mines Appalachian Experiment Station, dedicated last spring, was that the people of Morgantown, W. Va., wanted it to happen. In fact, they just about made it happen.

Before construction of the $2.6 million station, the various groups now housed in the modern, functional buildings were spread around in rented and donated space inadequate for maximum results.

The Coal Gasification Branch, Region V, conducted research at West Virginia University in space donated without charge by the school. The Div. of Petroleum Technology, Region V, worked at quarters in Franklin, Pa. The Morgantown Subdistrict, District C, Health & Safety Activities, worked out of headquarters at Fairmont, W. Va. The last-named group is responsible for administration of the Federal Coal Mine Safety Act of 1952 in 15 counties of northern West Virginia and two counties in western Maryland.

Thus when the Morgantown Community Assn., a subsidiary of the Chamber of Commerce, decided in 1946, when the first USBM office was located at Morgantown, that it wanted the kind of station the town now has, it was a call to action. The station is located on land given by the association for the express purpose of building the station. The group paid $25,000 for the land and transferred title to the Federal Government.

The station consists of seven functionally designed buildings. One of the most important projects underway is research into synthetic liquid fuels. Oil shale and coal are the most promising sources for synthetic fuels of the future. Shale research is being conducted in the West. The Bureau is pursuing the possibilities of coal at several USBM stations, including the Appalachian Station, in the East.

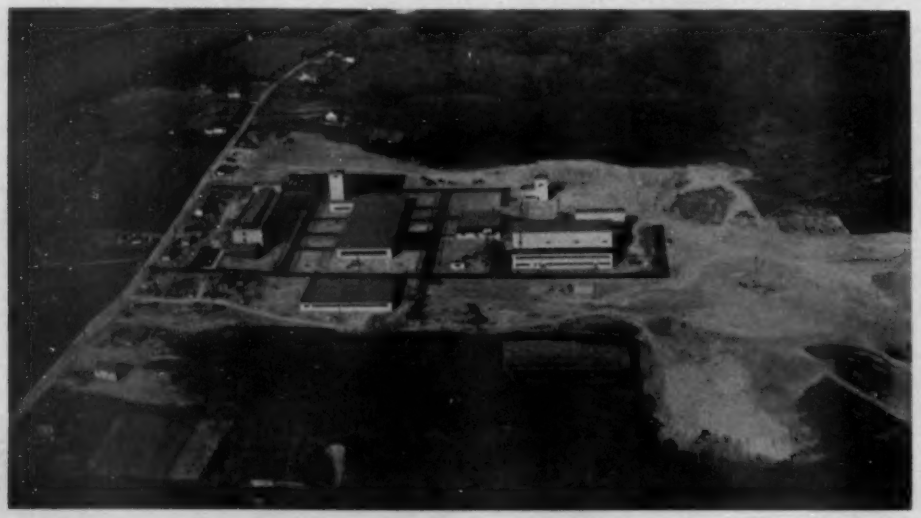
At the station, the Branch of Coal Gasification is composed of five sections: Pilot-Plant Operations; Gas Treating and Testing; Engineering; Data Evaluation and Planning; and Special Problems.

The Pilot Plant Operation Section is responsible for the gasification pilot plant and the oxygen-producing plant. It investigates methods for feeding coal into the gasifier and tests auxiliary equipment such as superheaters, pumps, and compressors.

The Gas Treating & Testing Section purifies raw synthesis gas, develops analytical methods, and makes analyses. Through laboratory and pilot plant scale experiments, it investigates and develops processes for removing hydrogen sulphide, carbon dioxide, organic sulphur compounds, and other impurities from synthesis gas.

The Engineering Section serves the other four sections of the Branch of Coal Gasification, as well as the entire station. The section designs and supervises construction, installation, and maintenance of pilot plant and laboratory equipment. It also assists in station maintenance and improvement.

The Data Evaluation & Planning Section collects, correlates, and interprets data obtained in the gasification and purification pilot plants. It also plans gasification experi-



This aerial view of the new Appalachian Experiment Station at Morgantown, W. Va., shows the plant which occupies land donated by the Morgantown Community Assn. Station consists of seven functional buildings.

This is typical of the kind of building erected at the station. It has no superfluous lines. It is almost severe in its simplicity, as are the other structures. They were designed for one purpose—research.

ments and makes preliminary appraisals of proposed new processes.

The Special Problems Section conducts fundamental research on special problems of general interest to the Branch of Coal Gasification. It usually works on the laboratory level, aiming at better understanding of chemical mechanisms and physical phenomena involved in reactions that occur during gasification.

At the dedication ceremonies Secretary of the Interior Douglas McKay saw the new station as part of the "tradition of the early, rugged mountaineers" who fought for free enterprise.

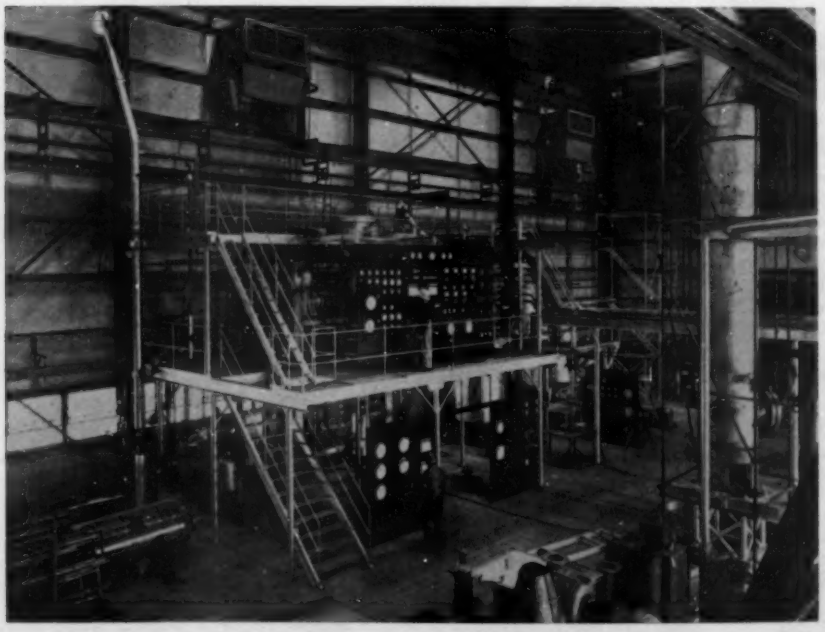
Mr. McKay termed the laboratories symbolic of "that partnership of industry and Government." Mr. McKay made special note of the role the university had played in the seven years since the establishment of the USBM headquarters in Morgantown. The university was especially significant in the setting up of the gasification program.

What of the 200 people who work at the Appalachian Experiment Station? They look upon the station with deep-rooted pride, happy that at last they have the kind of place to work where they can do the maximum. They know that what they have now is the best.

Boss of the experiment station is Sam S. Taylor, who has spent 21 years with the U. S. Bureau of Mines. In addition to being superintendent of the station, he is chief of the Bureau's Region V, Div. of Petroleum Technology.

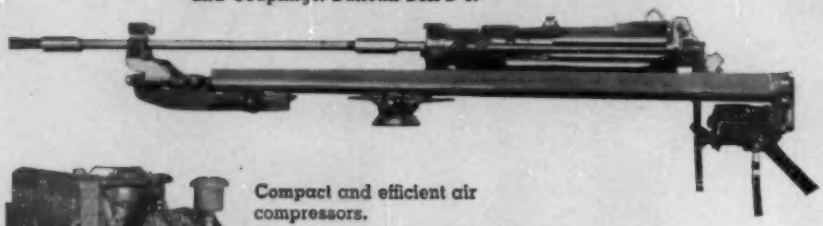
Photographs accompanying this article are by the U. S. Bureau of Mines.

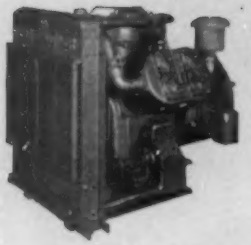
Interior Secretary Douglas McKay told the audience at the dedication, "It is the purpose here to gain fundamental knowledge which industry itself can develop for its own good and for the continued improvement of the American standard of living."



Pulverized coal is fed from the tall vessel at right into the gasifier (the flanged vessel behind the upper control panel) under pressure of 540 psi. Raw synthesis gas is cleaned in the scrubber to the left of the gasifier.

Low-cost development and production with engineered deep hole percussion drilling equipment. Deep Hole Drills, Ring Seal Shank, Long-Feed Mountings, Sectional Rods and Couplings. Bulletin DHPD-1.





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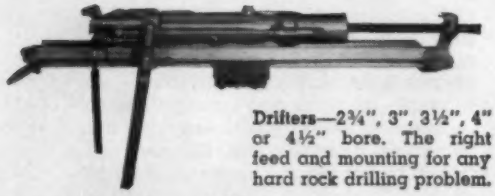

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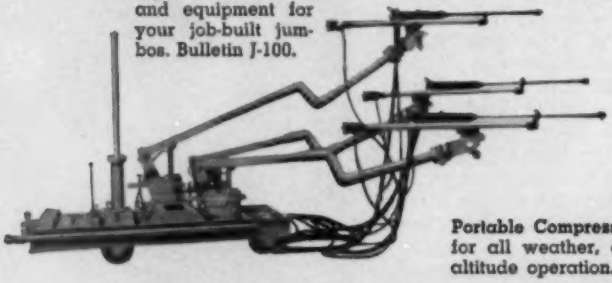

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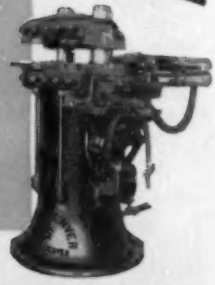

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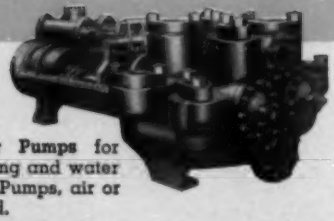

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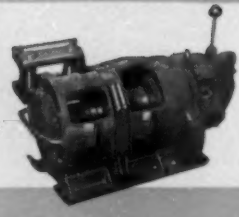

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Collector Addition, lb./ton	with AEROFLOAT 242	without AEROFLOAT 242
AEROFLOAT 208 Promoter	0.018	0.029
AEROFLOAT 242 Promoter	0.013	—
Amyl Xanthate	0.007	0.010
(Pine Oil, Sodium Cyanide and Soda Ash also used)		
Recovery, %		
Cu	93.3	91.8
Ag	78.5	65.5
Au	68.9	60.0
Tailings Assays		
Cu, %	0.080	0.143
Ag, oz./ton	0.0016	0.0026
Au, oz./ton	0.051	0.118

If you are having trouble making grade with suitable recovery, it will pay you to investigate the use of the AEROFLOAT Promoters, alone or in combination with each other or with xanthate. Cyanamid sells a complete line of xanthates, liquid and solid AEROFLOAT Promoters and a variety of AEROFROTH® Frothers, pine oil and cresylic acid. Please address your inquiry to our nearest office.

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Eagle-Picher Co. — From Mules to Mechanization

Until 1947 the Eagle-Picher Co., one of the nation's leading zinc producers, used many mules for underground haulage at its Miami, Okla., mining operations. That was the year the first diesel-powered equipment was lowered into the mine. The Allis-Chalmers HD-5 loader powered with a General Motors two-cylinder diesel engine was lowered piecemeal into the mine and reassembled.

Successful underground operation of the unit led to general mechanization and diesel-powered equipment now in use includes hauling vehicles, shovels, loaders, drills, and personnel cars. An underground workshop where equipment is assembled, serviced, and overhauled replaced the old stalls and haybins once used for the mules.

The replacement of mule-hauled cars with diesel-powered vehicles that can pull loads up to 20 tons, and diesel shovels and loaders has made possible an extension of activity that now covers some 85 miles of underground roads.

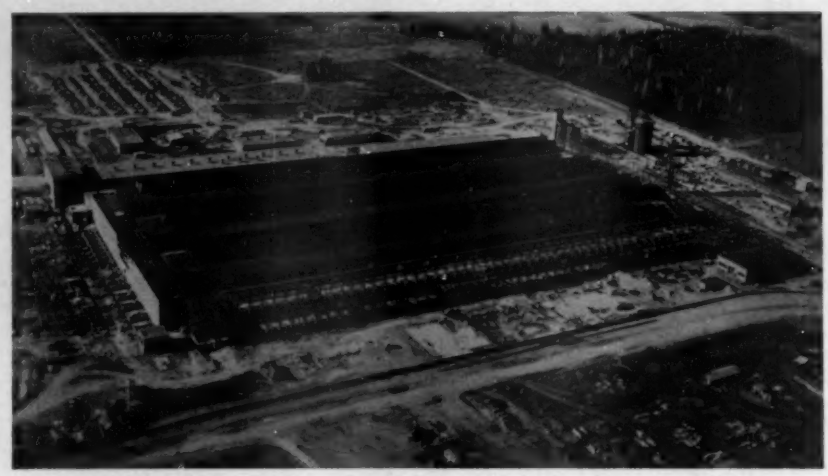
Mules used to do practically all the hauling at the Eagle-Picher operation at Miami, Okla. The lowering of the first diesel-powered machine into the mine meant technological unemployment for this fellow.

Workers get to the job in either diesel-powered personnel cars or in the vehicles they operate. This unit, formerly a small truck, is powered by a two-cylinder, two-cycle, GM diesel. First diesel-powered units entered the mine in 1947, spelling the end of mules in Eagle-Picher mining operations.

This GM diesel-propelled drilling unit works miles away from the mine entrance. Dieselizing has served to expand the company's operations over a tremendous area covered by an elaborate road system. Eagle-Picher began actual replacement of mules in 1943, when the first battery-powered equipment was brought underground. From 1943 to 1947 a combination of mules and battery power did the work.

Con Kelley Retires As Anaconda Chairman After 54-Year Career

Company Changes Name To Fit Diversification



The Anaconda Aluminum plant at Columbia Falls, Mont., is an example of the company's great diversification.

One of the copper industry's "fightingest" men has called it a career. Cornelius F. Kelley retired as chairman of the board of Anaconda Copper Mining Co.

Mr. Kelley plans to continue as a director of the company. He served Anaconda for 54 years—22 years as president. In his retiring address to stockholders Mr. Kelley said:

"Anaconda's future was never so bright. Many of the problems that have plagued us are now being solved and our entry into new fields will increase the stability of our operations."

Mr. Kelley was born 80 years ago at Mineral Hill, Nev., the son of a mine superintendent. The first money he earned came with summer vacation employment on Butte Hill, Mont., birthplace of Anaconda. Known as "Con" to many people, he went to work for Anaconda at 17 as a member of a survey team. Within three years he was in charge of survey and underground engineering in the Anaconda group of mines.

CORNELIUS F. KELLEY

He left Anaconda to study law at the University of Michigan and later returned to practice and enter politics. He was a member of the Montana House of Representatives between 1899 and 1901. He joined the legal dept. of Anaconda in 1901 and was on the front line of the company's bitter and long court fights over mining claims. In 1908 he became general counsel.

Mr. Kelley was the second recipient of the Charles F. Rand Medal, receiving the award from the AIME in 1944.

Company Name Changed

The same stockholders meeting at which Mr. Kelley announced his resignation voted to change the name of the company to The Anaconda Co. because of the firm's widening scope of activity.

The name change which took effect June 18 did not involve a change in company organization. Stock certificates with the old name will be honored until new certificates are available. Company assets are now $673 million, compared to $30 million at time of incorporation in 1895. Its copper fabricating operations, through the American Brass Co. and Anaconda Wire & Cable Co., are now the largest in the world. Development of the Butte mining area has made Anaconda the largest manganese producer in the U. S., with about 90 pct of domestic production to its credit.

The company's operations include a uranium ore processing plant near Grants, N. M., and development of large-scale open pit uranium operation about 50 miles from Grants. A subsidiary, Anaconda Aluminum Co., is building a $65 million primary aluminum reduction plant at Columbia Falls, Mont.

Succeeding Mr. Kelley as Anaconda chairman is Roy H. Glover, vice president and general counsel of the company. Mr. Glover joined Anaconda at Butte, Mont., in 1943. He became vice president and general counsel in 1951.

Mr. Glover earlier this year received the Order of Merit of Bernardo O'Higgins. It was conferred by President Carlos Ibañez del Campo of the Republic of Chile.

Mr. Glover was born in Goldendale, Wash., July 15, 1890. He earned his law degree at the University of Washington in 1915, practicing later in Portland. He was admitted to the Montana bar in 1918, following World War I service.

Jackpile mine is a multimillion ton uranium bearing sandstone ore deposit being developed by Anaconda. It's located about 50 miles from the company's ore processing plant at Grants, N. M.

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SOMETIME later this year Pittsburgh Consolidation Coal Co. will start construction of the first commercial pipeline for transportation of coal. The coal will move from the company's Georgetown, Ohio, mine to Cleveland Electric Illuminating Co.'s plant near Cleveland, 108 miles away. In announcing the plan for construction of the pipeline, Pittsburgh Consolidation stated that it would be built with the cooperation of the New York Central RR, the New York, Chicago & St. Louis RR, and the Pennsylvania RR. The announcement also said that the railroads "are in a position to take substantial ownership of this new means of coal transportation when construction is completed."

The pipeline is being built to circumvent what Cleveland Electric considers high rail costs to the Lakes. The pipeline right-of-way from Eastern Ohio to Eastlake, where the power plant is located, will have to go under rail lines at 11 points. *The Wall Street Journal* states that it is understood that to offset the possibility of law suits, the coal company gave the railroads ten-year options to buy into the line.

It will cost between $9 and $10 million to build the pipeline, which is expected to have a capacity of at least 1.2 million tons per year. Coal will move through the line as slurry. The contract between Pittsburgh Consolidation and Cleveland Electric calls for about 18 million tons of coal to be delivered over a 15-year period. The Eastlake plant has three generators going and uses 3000 tpd. Consumption of another 1000 tpd is expected when a fourth unit goes to work. Part of the plant's coal needs will continue to be supplied by rail—just as most of the Georgetown production will continue to be shipped by railroad.

New York reports indicate that there is some talk of reducing coal rates from about $3 per ton to about $1.60 for coal moving from eastern Ohio to Cleveland, in order to stop construction of the pipeline. Since rail executives feel the action might not conform to common carrier provisions of the law, it's not likely to happen. But if the law is changed along lines suggested by the President's Cabinet Committee on Transportation, it may be possible for railroads to sign special bulk transportation contracts. Request of the Commerce Dept. to introduce legislation in both houses to implement suggested changes has already been complied with.

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HOW long would it take the U. S. to swing into full wartime production in the event of a national emergency? D. J. Davis, vice president, manufacturing, Ford Motor Co., feels that there are several inherent weaknesses in the *deep-freeze* technique currently in vogue. While he feels the theory itself is sound, "in the event of a national emergency, entire war plants and their equipment now held intact under the deep-freeze concept would have to be reactivated in order to resume production of war goods."

The deep-freeze plan would make it possible to start production in months instead of years, but the approach is extremely costly. The facilities are established, then placed in deep-freeze storage—to be used only if war comes. Complicating the problem is the matter of obsolescence. "While it is true that military items such as tanks do not normally become obsolete overnight, they are subject to what might be called obsolescence by attrition."

Mr. Davis offers as one approach sound defense mobilization planning on a continuous and long-term basis. Speaking at the 10th annual meeting of the National Assn. of Engineering Companies, he said, "To promote consistency among the many industrial plants involved in war production, to permit the most economical procurement of facilities used in production, and to eliminate or minimize obsolescence of military items, we feel that the essential principles used by industry in advance planning are equally important, and equally applicable, to the planning and execution of the vast program of wartime production and operations."

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THE technical writer may not be aware of it but he is right smack in the middle of a fight. He is battling for readers. The lack of understanding some technical writers have of the situation is costing them the people they most want to reach. Because of the tempo of modern living many people do their reading in a catch-as-catch-can way, reading on subways, suburban commuters, airplanes, between the supper dishes and bedtime, and other odd moments in the day. In almost every case the reader is surrounded by distractions—the strictly entertaining slick magazines, car advertisements, radio and TV, and hundreds of other media designed to lure him from whatever he is doing.

Thus the technical writer, often dealing with extremely involved material, is in a kind of free-for-all battle royal. John Stahr, editorial director of Carl Byoir & Associates, directed some pretty sharp criticism of technical writing in a speech to the writers for *Instrumentation*, the external technical publication of Minneapolis-Honeywell's Industrial Div. He deplored industrial gobbledygook, comparing it with the government variety.

"Your magazine competes for attention with scores of publications which can devote themselves to giving the reader an hour's amusement. Writing that is warm-blooded and incisive, and free of traditional but tiresome tricks of pompous phraseology, is increasingly necessary these days even for men writing on highly technical subjects. If the lead sounds like a patent application you are going to lose the reader before you seize him."

Some of the more objectionable kinds of writing were illustrated by Mr. Stahr. He cited such phrases as "initiate or terminate the pumping action," instead of "start or stop pumping," and "experiment

takes place under conditions of elevated temperatures," instead of "occurs."

Mr. Stahr advised the Minneapolis-Honeywell writers to have no fear of telling about a new process or product in nearly the same terms they would use in telling the same tale to a neighbor between sorties with the lawn mower. The elaboration and detail that the reader is entitled to need not be crowded into the opening paragraphs.

"Remember this: a lot of the readers, even of technical magazines, are not necessarily graduate engineers or persons thoroughly steeped in engineering jargon. And yet they may be company executives on whom it is particularly important to make a favorable impression. You can lose and alienate that kind of reader by language that is too stuffy and too technical. But you'll never lose or estrange even the most scholarly technical man simply because you tell a story in terms of hard-hitting basic English—if the subject matter itself is worthy of his attention in the first place."

Mr. Stahr gave two important reasons for the development of a concise writing style similar to those of "a top-notch newspaper reporter." One is the "sheer increase in volume of technological developments nowadays that deserve reporting," and the other is the great increase in demands on the reading time of executives.

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SCIENTISTS at Battelle Memorial Institute have developed a new method for identifying minute concentrations of impurities in the air. The method involves *longpath* infrared spectrophotometry and has the advantage of being extremely sensitive and accurate.

The system is based on the principle that specific substances in the air absorb certain wave lengths of light. Light is absorbed in proportion to the amount of the impurity in the air. By projecting an infrared beam through a 175-ft gap of air and measuring the type and amounts of light absorbed, small concentrations of impurities can be qualitatively and quantitatively analyzed. The method is much faster than the usual collecting of samples for chemical analysis. Impurities are detected directly and instantaneously. Possible uses other than in industrial and municipal atmospheres are prospecting for petroleum and natural gas and detection of hazards to humans and animals from mass spraying of farm acreage.

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AUTOMATION is getting to be almost as familiar a word as *ain't*. The latest thing is a driverless tractor train that can be summoned almost anywhere in a plant by simply pushing a button. The latest in material handling magic was shown at the National Materials Handling Exposition in Chicago, when a fully loaded tractor train made its way through a plant to the shipping room. The train follows a route set by a guide wire strung from the ceiling. It's called the Guide-O-Matic and is the latest development of the Barrett-Cravens Co. The setup is completely automatic with neither operator nor physical connection required. The load moves steadily toward its terminus at any chosen speed, completely under automatic control all the way.

Radio waves transmitted over the wires control the trucks. Transmission is through signal boxes at desired locations throughout the plant. To call a truck, one simply presses a button and the unit comes immediately to the station where the signal originated. The waves are picked up by a *sniffer* box mounted on the truck from the overhead guide wires. In the box is an electronic brain that answers commands instantly. The train follows the route set by the guide wires. Route can vary and serve many destinations. The wire can be set in a slot in the floor or strung overhead.

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CANADIAN aluminum reaching fabricators in the U. S. has shown a steady increase since 1949. This year some 225,000 tons are expected to enter this country. Aluminium Ltd. has been energetically wooing the independent fabricators, despite the 1.5¢ per lb. duty it must absorb. Aluminium Ltd. sold to only seven U. S. fabricators in 1946 but today is serving more than 100 firms. What's more, shipments to the U. S. are expected to jump to a total of 290,000 tons in 1956, according to Nathanael V. Davis, president of Aluminium Ltd.

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LOOKING into its crystal ball, the Bank of Montreal has a vision of a possible 25 million ton per year iron ore production for Canada in the next five years. This would be a tripling of current production. The bank even goes further by saying that the St. Lawrence Seaway may even bring about a 35 million ton per year production. A 25 million ton production would boost Canada from eighth place to fourth place in world iron ore production.

Right now principal markets for Canadian ore are the U. S. and Europe. The bank quotes the Paley report as evidence that U. S. dependence on foreign ore sources will grow greater and it notes that European reserves are insufficient to meet projected European requirements. One of the principles of blast furnace operation is to continue to use the kind of ore to which the furnaces are accustomed. Thus the bank sees some Canadian furnaces continuing to import U. S. ore rather than relying on the Canadian product. In addition to the belief that Canadian ore will replace dwindling Mesabi range supplies, the report indicates that current exploration may be successful in turning up new Canadian sources.

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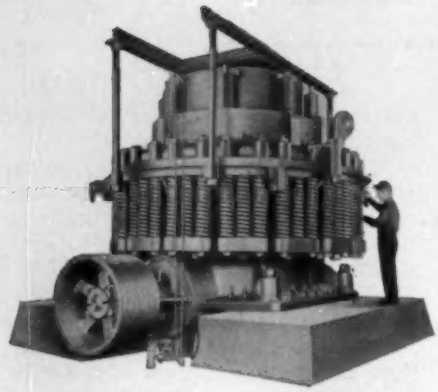

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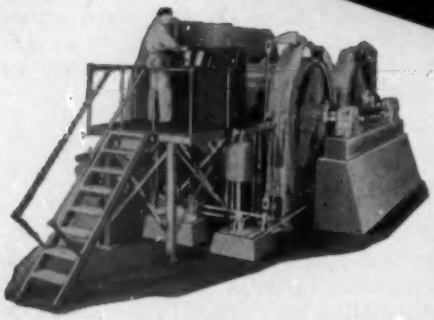

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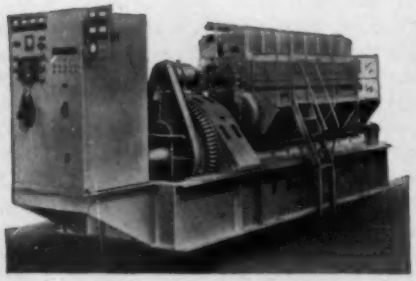

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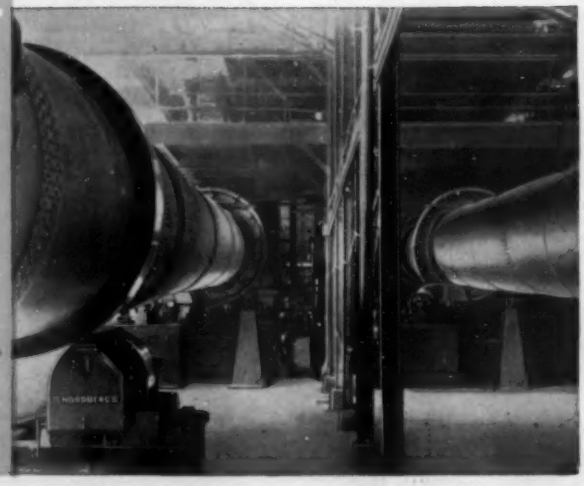

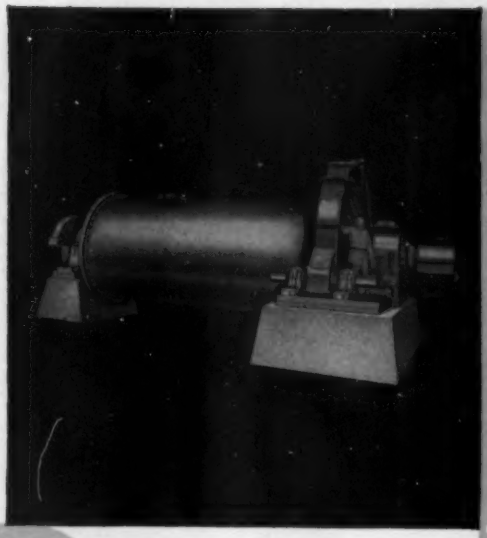

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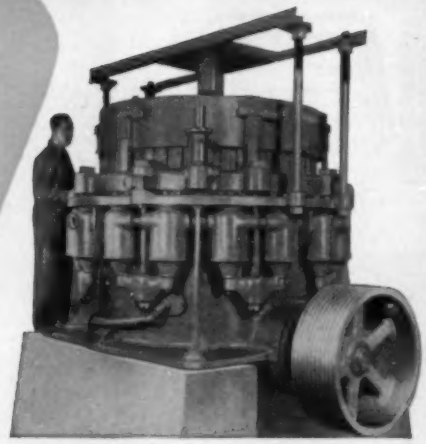

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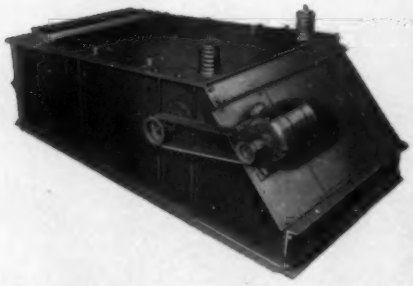

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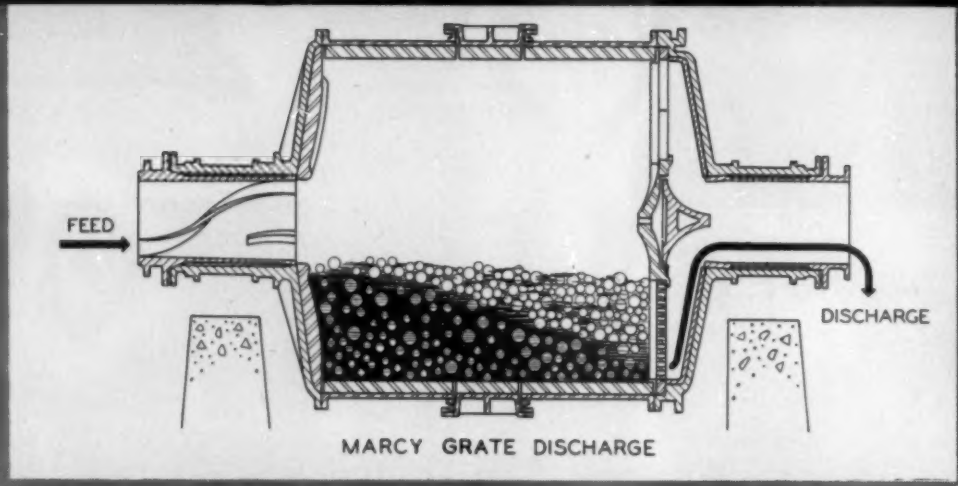

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"IT is clear that stones are generated as plants are—gold gives birth to gold, gems to gems, stones to stones . . . Each specie reproduces and multiplies itself . . ." Thus wrote Prof. M. J. C. Schweigger in 1665. This and a myriad of other startling geological ideas turn up in an evening or two with a book by Frank Dawson Adams. Recently reprinted, *The Birth and Development of the Geological Sciences* (see *Books*, June 1955, page 513) provides the modern day reader with some healthy humility about the infallability of science as well as providing a bird's eye view of the historical development of the earth sciences.

One gains strong respect for those men willing to go out and actually look at the earth. These men who based their ideas *on observation* began to bring some order out of chaos and superstition. But some of the problems remain unchanged, it seems:

> The Jesuite Bernardus Caesius writ a volumious Piece of Mineralogie, or Natural Philosophy; wherein, though he expatiated too far to fetch in all things that might seem any way of kinred to that kind of knowledge; and that it was but a meer Collection and heap stoln from other Authors, and hardly any thing except notions; yet is there something in it (especially concerning the signs of discovering Mines and Ores) that may advantage such a Reader, as hath the skill, or will take the pains to sever the tares from the wheat, and separate the gold from the dross.

This was John Webster writing in 1671 about a publication dated 1636. Change the spelling and punctuation and it becomes the timeless plea of the man in search of a usable fact.

The book by Adams has a wonderful section on the period of the Neptunists, picturing how the magnetic personality of one man drew so many to follow a rather short-lived and somewhat fantastic theory. The same man nonetheless fired the enthusiasm of a host of able workers like Humboldt who were to scour the world for evidence to fit the teacher's theory—and who in so doing were to lay the foundations not only of field geology but also of later and sounder explanations.

The same section that discusses the Neptunists and Plutonists brings out repeatedly that it wasn't until geologists actually began to study the ground that theory could move ahead. In fact the start of progress in mineralogy as well as in historical and structural geology seems largely to trace to the influence of the practical miners of the Freiberg school in the Erzgebirge region of Germany. In an era begun by Agricola and closing with Werner, this region stimulated common sense in observation and thinking.

The origin of ores was of natural concern to this major mining region, and after discarding the more fantastic philosophical ideas, the miners early arrived at a pretty modern-sounding idea of metal deposition. Agricola writing in the middle of the 16th century expressed the germs of two modern hypotheses: the theory of ascension and theory of lateral secretion.

For some problems the solution hasn't been as rapid as might have been expected. The means of occurrence of the very intrusives that vexed the followers of Werner and neptunism is still a bone of contention. One speculates as to whether or not more recent explanations such as granitization might not eventually meet the fate of those ideas earlier "dashed on the rocks."

How silly are our ideas going to look in 2455? It looks as if the only safe ground is observation and more observation. Aristotle had the last word when he said: *"He who sees things grow from the beginning will have the best view of them."* No one that we have heard of has had this advantage.

AFTER dinner speaking can be art or agony; in fact there are those who claim that listening to it is the only proved cure for hypertension and insomnia. Most of us have long recognized the existence of the literary ghost, but here are some sample speeches stocked by one firm of ghost writers:

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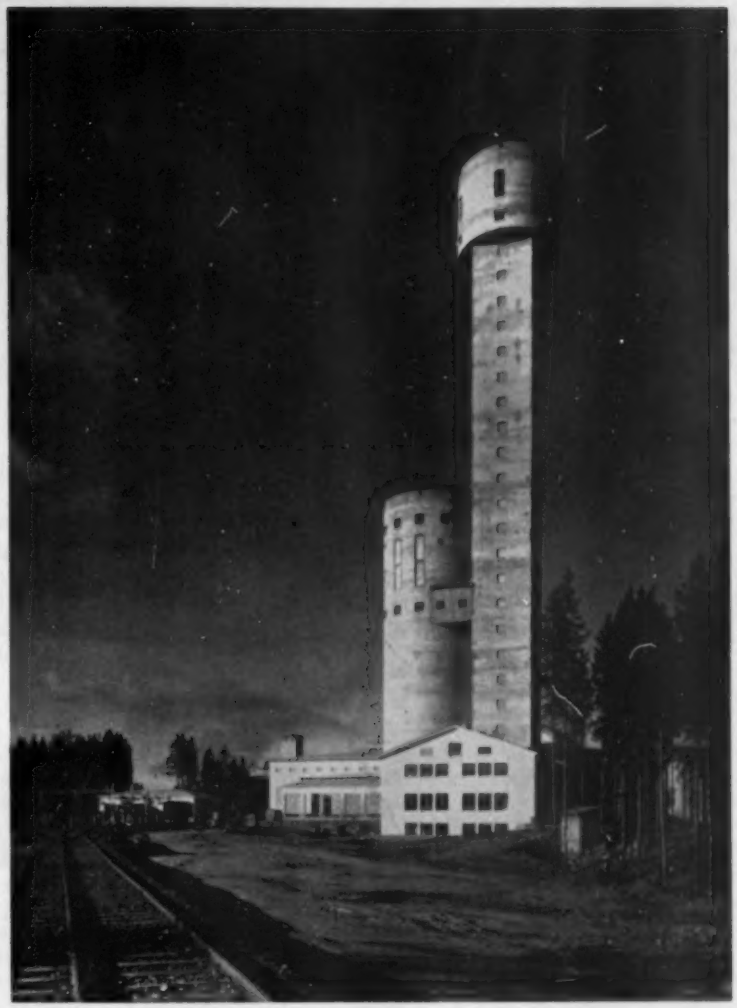
Finland's Outokumpu Mine

The Mine — The Shaft — The Mill

The lofty headframe-hoisting installation — ingenious mining method — up-to-date mill are high points of this major European copper-zinc producer.



by E. Hakapaa, H. Tanner, and V. Vahatalo

Recently modernized, the surface plant of the Outokumpu mine in Finland incorporates a number of ideas meriting close scrutiny from this side of the Atlantic. The mining methods make extensive use of concrete in some unusual ways. Design of the headframe and surface plant represents the latest thinking of European engineers and includes an integral Koepe hoist.

THE deposit is in eastern Finland, province of North Karelia, 30 miles west northwest of Joensuu and at 60°44′ N. latitude. Pyrrhotite, pyrite, chalcopyrite, and sphalerite mineralization occurs in a shear zone in quartzite near a body of serpentinite. Two lenses have a total length over 12,000 ft, with remaining reserves of the 3 to 4 pct Cu ore estimated at about 15 million metric tons.

The deposit was discovered in 1910 by Otto Trüstedt. A glacial float found two years earlier about 30 miles southeast of Outokumpu gave the impetus for the investigations. Tracing the float led prospectors to the Outokumpu district, where diamond drilling began in September 1909. After two unsuccessful holes, ore was found in a third drillhole, March 1910.

E. HAKAPAA is General Superintendent, H. TANNER is Mine Superintendent, and V. VAHATALO is Geologist, all of the Outokumpu Co., Finland.

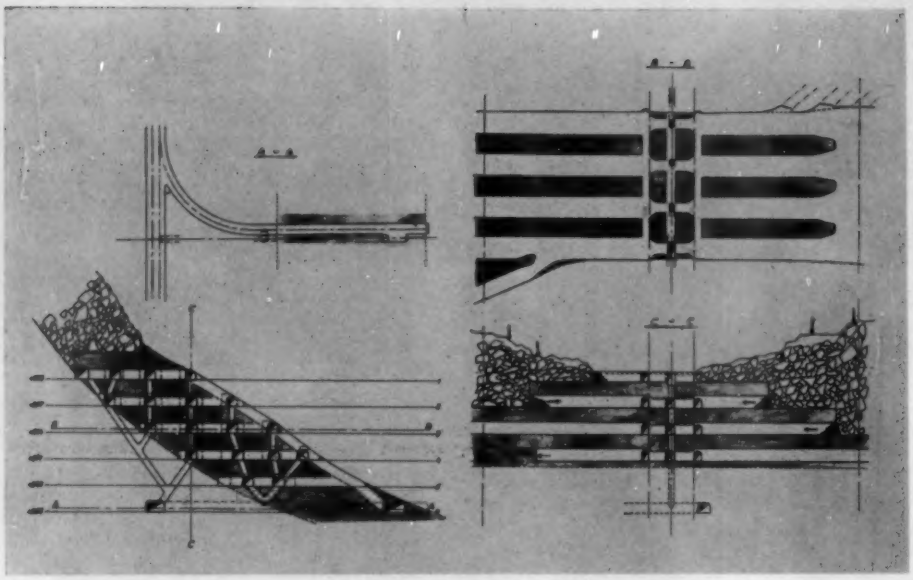
Discovery and History

At first the deposit was worked on a small scale, and an experimental plant for producing copper by the hydrometallurgical method was built in Outokumpu. Not until the railway between Joensuu and Outokumpu was completed in 1928 could development of the mine into a really important enterprise begin.

During 1927 and 1928 a new shaft, the No. 1, a concentrator, a steam power plant, and other buildings were constructed. In the beginning the mine produced about 100,000* tons of ore per year, but production increased every year, reaching 400,000 tons in 1939. In 1940 shaft No. 2 was completed and since then yearly production has been about 600,000 tons, except for a few lean years during the war.

* All figures are in metric tons, approximately 1.102 short tons.

Originally the copper concentrate was shipped out, but in 1936 the company's own smelter started operation. At this time the copper content of the yearly production already amounted to 12,000 tons. The copper concentrate was smelted in an electric furnace and the blister copper was exported.



LEFT:
Top slicing is used where hanging wall is weak.

OPPOSITE PAGE:
Photographs show both scraper slide used where dip is over 12° and shovel loading with Eimco on crawlers in pillar mining.

In addition to the flotation of chalcopyrite, the separation of pyrite and pyrrhotite from the ore in a joint concentrate was begun at the concentrator, and Finnish pulp mills were encouraged to use it instead of the foreign sulphur. During 1940 to 1941 an electrolytic copper refinery and a rolling mill for metals was built in Pori and the export of blister copper stopped.

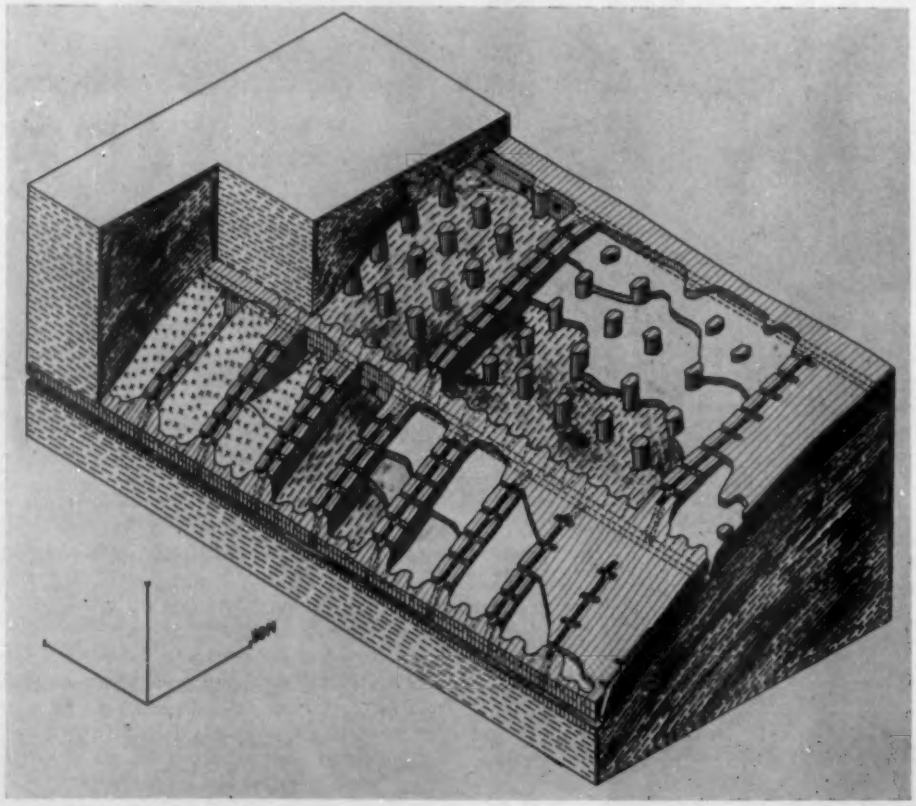
By 1950 it was determined that the surface plant and mill had become inadequate. A new shaft was sunk in 1951, construction of a new mill and surface plant was begun in 1953, and the wholly new plant described here began full-scale operation at the end of 1954.

Stoping Methods

Factors bearing on the choice of stoping method vary in different parts of the ore deposit, and three principal methods of stoping have been applied in the Outokumpu mine: open stoping with casual pillars, top slicing, and room-and-pillar method.

Compressive strength of the ore is quite high, but its tensile strength is low. Shearing in the ore is fairly scarce. The quartzite of the hanging wall has about the same characteristics as the ore, except that its fracturing is more intense. The serpentinite occurring as the country rock and sometimes as the host rock of the ore has varying characteristics depending on the degree of serpentinization and on the amount of the talc-filled joints and slips. Mica-schist below the footwall is the firmest and strongest of the country rocks.

Open Stoping with Casual Pillars: This method was used in the upper parts of the deposit almost exclusively until 1944. Haulage drifts, partly cut into



Open stoping with casual pillars was used almost exclusively until 1944 in the upper parts of the deposit.

the footwall, were driven at vertical intervals of 114 to 131 ft.* Drifts were connected with raises driven at intervals of about 328 ft. Stopes were developed like shrinkage stopes, leaving an ore pillar above the haulage level and using chutes to draw the ore to the cars. The dip of the ore deposit was usually so flat that scrapers had to be used to drag the broken ore to the mill holes above the chutes. In thicker parts the deposit was mined in two slices, taking the upper slice first.

In the upper levels the hanging wall country rock was firm quartzite, so that only casual ore pillars could be left to support the roof. However, in lower levels the hanging wall became weaker, partly because of increased rock pressure and partly because the layer of quartzite became thinner while the ore deposit was thicker. Spacing of the supporting pillars had to be decreased and size increased, so that too much of ore was wasted in pillars.

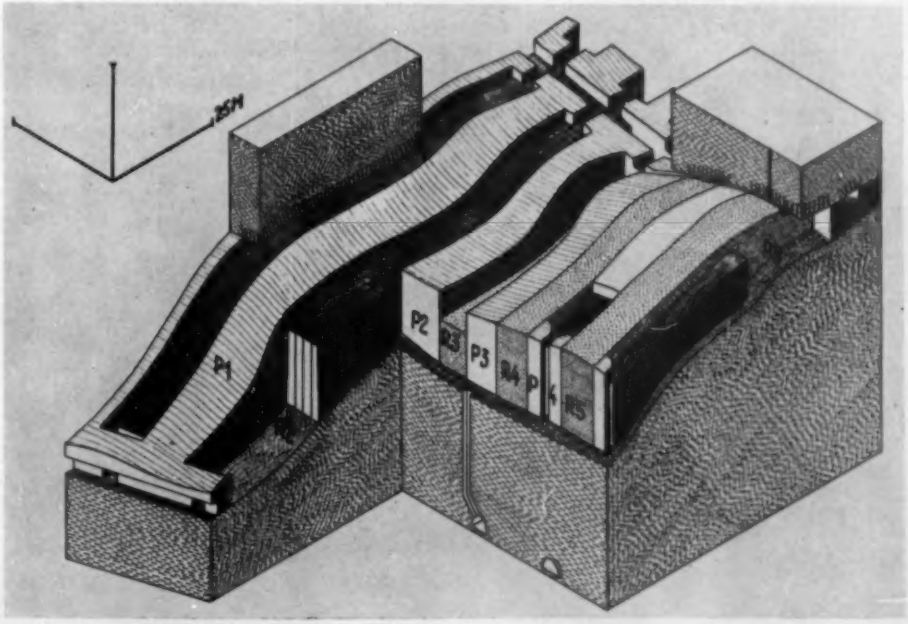
In 1939 stope width was cut down to 52.5 to 65.6 ft. In order to mine the raise pillars the stopes were filled with classified sand from the mill tailings, carried down through rubber-lined pipes. This type of open stoping was considered favorable in those parts of the Outokumpu mine where the thickness of the ore deposit was below 32.8 ft and the roof so strong that less than 5 pct of the ore was lost in pillars.

Top Slicing: In deeper parts of the orebody the hanging wall turned out to be too weak to stand even over a short span of the narrow stopes. Starting in 1943, therefore, top slicing was applied. Crosscuts were driven from the haulage drifts through the orebody at about 328-ft intervals. Service raises were put up from each crosscut and separate chute raises for the ore were driven from the haulage drifts.

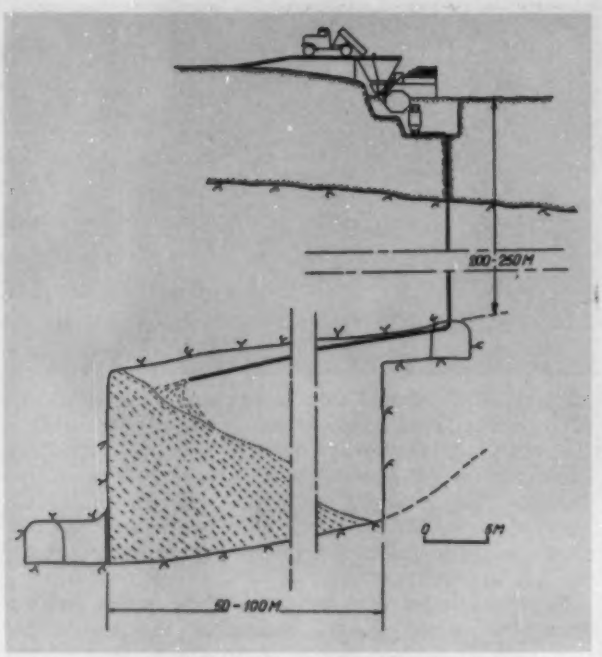
Sublevel crosscuts for each slice were driven from the raises to the walls of the ore. The thickness of a slice being 20 to 22 ft. The drifts of the slices were driven in opposite directions from the sublevel crosscuts for about 164 ft. Direction of the drifts depends on the dip of the walls, on the shape of the horizontal slice, and on the loaders or scrapers. Usually the drifts of the slices are parallel and at right angles to the sublevel crosscuts, at about 39-ft intervals.

Principally for safety the roof holes and the wall holes of the slices are drilled beforehand so that there is always 16 ft from the face ready for shooting. Owing to the strength of the ore no timbering is needed. However, dilution of the ore with the waste rock to a certain extent cannot be prevented. Lately scrapers have been used exclusively. Top slicing at Outokumpu provides relatively safe working conditions. There are, however, several disadvantages. Stope development is extensive and costly, and ore recovery is not satisfactory. In scraping all water goes down to the ore raises, forming slimes which cause trouble in haulage, hoisting, and flotation. Caving of the capping has also extended too

* Unrounded or odd dimensions result from conversion of metric figures to English system.



Room-and-pillar stoping with delayed filling is newest method at Outokumpu. Legend: R1, ready for drilling; R2, mining a room; R3, filling an empty room; R4 and R5, already filled rooms; P1, P2, and P3, pillars; P4, developing a pillar; P5, mining a pillar.



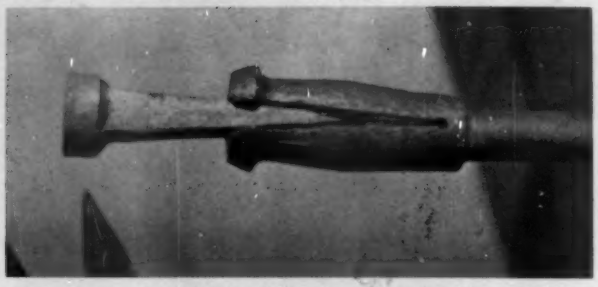
Section shows method of filling through 6-in. boreholes used with room-and-pillar mining method.

far, sometimes resulting in subsidence of the surface which must be prevented in the western part of the crebody that is under an area of lakes.

Room-and-Pillar Stoping: The newest stoping method in Outokumpu is a room-and-pillar stoping with delayed filling. Width of rooms and pillars is 26.2 ft. Stopes are parallel with the dip and stope length varies from 164 to 328 ft.

A stope is opened by carrying a 26.2-ft heading 8 ft high at the top and in contact with the hanging. The exposed roof is bolted by a predetermined plan.

Vertical holes are drilled with sectional steel parallel down to the foot of the ore, and length of the holes varies from 23 to 49 ft. In a stope 26.2 ft wide there are four or five drillholes in a row. Burden varies from 3 to 5 ft depending on hole length. All the holes of a stope are drilled before blasting is started. Drill footage is checked and recorded, and samples are taken from the holes of the middle row to determine average grade of ore. Blasting is with 45 pct dynamite and short-delay detonators. One row at a time is blasted, giving 400 to 500 tons of broken ore.



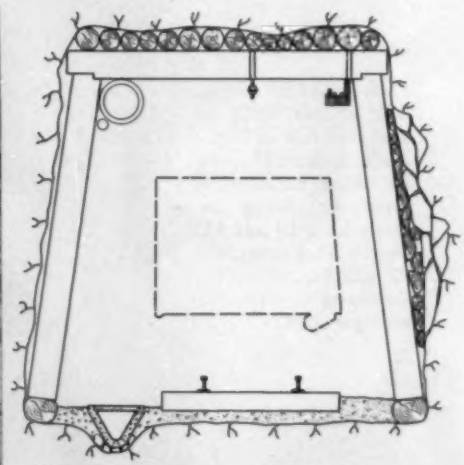
Anchorage of roof bolt with wedge driven in shows special style developed to get adequate anchorage in soft serpentinite.

Loading in Room-and-Pillar System: The system used in moving ore in a stope depends on the dip of the footwall. If the dip is below 12° ore is loaded into dumpers either with a scraper-slide, a power shovel, or an Eimco loader on crawlers. The dumpers transfer the ore to the nearest ore raise. When the dip is over 12° ore is transferred from the face to the ore raise with 50-hp 3-drum scrapers.

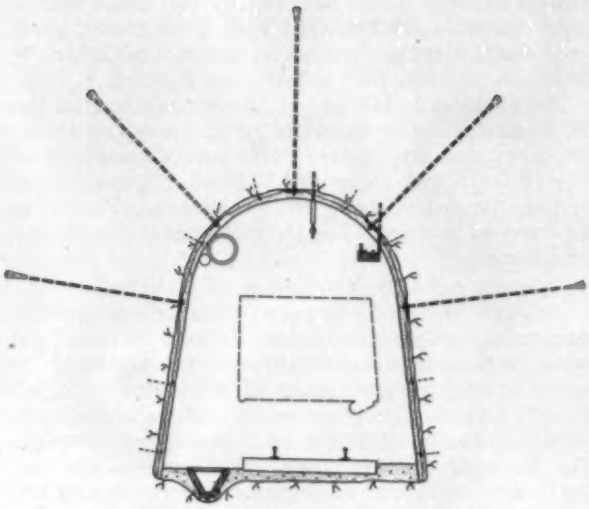
Filling: Immediately after completion of a stope the filling is introduced from the surface through 6-in. boreholes. The holes at 328-ft intervals are drilled with churn drills. Filling material is distributed by rubber-lined pipes. A quite lean mixture of concrete is employed as filling material, made up of one part mill tailings and two parts of sand. The water-cement ratio is 2:1. From the mixing stations filling is blown down to the stopes in 0.65-yd portions. The two mixing stations each have a capacity of about 13 cu yd per hr, and plans are set for a central mixing station. The compressive strength of a 3-month old concrete fill is about 30 kg per cu cm. In 1954 about 65,000 cu yd of concrete was produced.

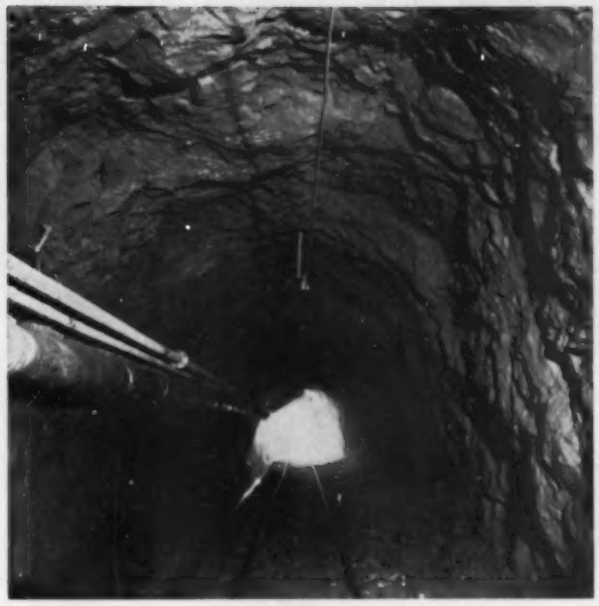
Pillar Extraction: Pillar extraction is started after hardening of the concrete fill. The top of the pillar is first cut out the same way as in the opening of a room, and the exposed roof is bolted. At the same time and in the middle of the pillar an 8x8-ft drift is driven along the footwall. In the upper end of the stope a short raise is driven from this drift to connect to the roof opening and to open up a heading of the stope. Drilling is done from the roof opening with sectional drill steel and broken ore is scraped out through the foot drift.

So far the concrete pillars have lasted well and their walls have stood up in good condition during the mining of pillars. Probably the pillars could be



Photograph and section show timbered drifts used in serpentinite.





Section above shows the roof bolt layout for drifts and photograph at right shows an arched drift. Both types are used except in serpentinite.

mined the same way as the rooms. The completed stopes are filled through boreholes with pit sand, using enough water to make it flow. In the last phase the horizontal pillars are mined on the retreat.

Advantages of this System of Mining:

1) Safety: the back is well supported and under control.
2) It gives clean ore.
3) Ore recovery is high, about 95 pct.
4) As some of the ready-drilled stopes can be kept in reserve an even production is guaranteed in spite of the yearly fluctuation of manpower.
5) Grade of mill feed is known beforehand and can be controlled.
6) The long drillholes allow effective breaking of the ore. As every blast gives a large amount of broken ore, loading equipment can be used effectively.

The main disadvantage of the method is that it is rather expensive, the cost for cement being considerable. The advantages, especially the rather small dilution and the high recovery of ore, make its use in Outokumpu's fairly high grade ore possible.

Drilling

Outokumpu mine uses exclusively Atlas type RH-656-2W rock drills. These are used as jackhammers in longhole drilling. A special air leg is used in horizontal drilling and another type of air leg for drilling in raises or for roof bolting.

Drill steels is ⅞-in. hexagon, tungsten carbide tipped, with collared shanks. Drilling lengths are 3.28, 6.56, and 7.87 ft with bit diameters of 1.33, 1.29, and 1.26 in. In spite of the high quartz content of the ore drilling rate is 9.8 to 15.7 in. per min. Consumption of the tungsten carbide tips is rather high and an average of only 164 ft can be drilled.

Longholes are drilled with sectional steels joined with extension sleeves. The threading is done in the tapered ends of the sections. The sections are made of drills whose bits have been used up and the 1.49-in. diam steels are 20 in. long.

Roof Bolting

Roof bolting was first tried in Outokumpu in 1950. There were some difficulties in finding an anchorage that would be strong in soft serpentinite, since the slit-and-wedge type of bolt and the expansion-shell

Geology of the Outokumpu Deposit

The deposit lies in a shear zone in quartzite at, or close to, a body of serpentinite conforming in its general trend to that of its surroundings. It consists of two slightly overlapping highly elongated lenses, of which the so-called Kumpu-lens is divided by a fault into two separate bodies.

Total length of the orebody is about 12,465 ft, it is 984 to 1148 ft wide, and the thickness averages 29.5 ft. The remaining reserves (1954) are estimated at about 15 million tons, averaging 3.71 pct Cu, 28.19 pct Fe, 24.75 pct S, 1.07 pct Zn, 0.2 pct Co, 0.1 pct Ni, and 41.97 pct gangue (chiefly quartz).

Three main ore types can be distinguished: 1) Disseminated ore, 2) *Normal* ore, and 3) Brecciated ore. The disseminated type occurs in the contact zones against the footwall and hanging wall and along the upper edges of the lenses. The normal type is dominant in the central zones of the swellings and towards the hanging wall, while the brecciated type appears in the transitional zones between the two.

Essential minerals of the normal ore type are pyrrhotite, pyrite, chalcopyrite, and sphalerite. As accessory minerals there are valleriite, linneite, pentlandite, galena, stannite and, associated with silicates, magnetite and chromite.

On the basis of its structural features and contact relations the ore is distinctly epigenetic. First a relatively pure disseminated pyrite ore evolved in the weakly disturbed quartzite. This mineralization was caused by a hydrothermal solution, produced from a cooled gas phase and attendant water vapors, which both preceded the intrusion of the normal ore. In continuation the pyritic disseminated ore was crushed and a concentrated sulphide solution intruded into the pressure minimum. In the central parts of the zone of disturbance the massive normal ore type evolved in the open folds parallel to the schistosity.

Structure and mode of occurrence distinctly point to an intrusive origin and the ore solutions were pneumotectic in nature, i.e., they first separated from some magma after its main crystallization and were relatively hot. According to the geological thermometers occurring in the mineral paragenesis, the temperature during the formation stage of the normal ore type was about 400 to 500°C.

plug did not fill the requirements. After several tests a special anchorage was developed. The bolts are made of soft steel 0.69 in. diam, 7.8 ft long. The wedges are hammered in with a conventional rock drill and the nuts are tightened with air impact wrenches. The bolts are pre-stressed to about 8800 lb.

Bolting is used to reinforce the roof in stopes, in main haulage drifts, and in larger openings, such as the crusher room. In workings that have a life over 10 years galvanized bolts were used, but now the bolt holes are grouted with fine concrete mix. In main haulage drifts and in rooms that have a long life, in addition to bolting, the roofs and walls are covered with wire netting and sprayed with 1.9 to 3.9 in. of concrete by means of a cement gun.

Walls of the underground ore bins are reinforced with bolts made of deformed structural steel. After the nuts are tightened, the bolt holes are grouted with fine concrete mix so that when the nuts are worn out the bolts are still kept in a pre-stressed condition. About 15,000 roof bolts are used yearly.

Haulage

The main haulage drifts are on the 1049-ft level. All broken ore is brought down by ore raises and dumped through loading chutes to the cars. This level is entirely below the orebody. All drifts driven in serpentinite are timbered with impregnated pine. In the other rocks—quartzite, skarn, and schists—drifts are arched, roof-bolted, and gunited.

The 60-lb rails are joined by arc welding. In the drainage ditches of the drifts 3-ft prefabricated concrete sections are utilized. Ore trains consisting of 8 to 10 Granby-type cars of 123.5-cu ft capacity are pulled by 8-ton trolley locomotives. Traffic is directed by a dispatcher through signal lamps and telephones.

Ventilation

Owing to the high (50 pct) free silica content, the dust is dangerous. Only wet drilling is done and water atomizers are turned on after blasting. In spite of that several cases of silicosis developed. In 1950 a ventilation shaft was sunk. Two fans, each with a capacity of 58,800 cfm, ventilate the mine. The ventilation shaft is normally used upcast, but ice formation in the hoist shafts sometimes necessitates reversing the air flow during the freezing season.

By means of effective ventilation average dust count of mine air is now about 80 particles per cu cm. No new cases of silicosis have been recorded lately. In sampling airborne dust the Konimeter and Tyndallmeter have been used.

Finland's Outokumpu Mine

Keretti Shaftplant and Mill

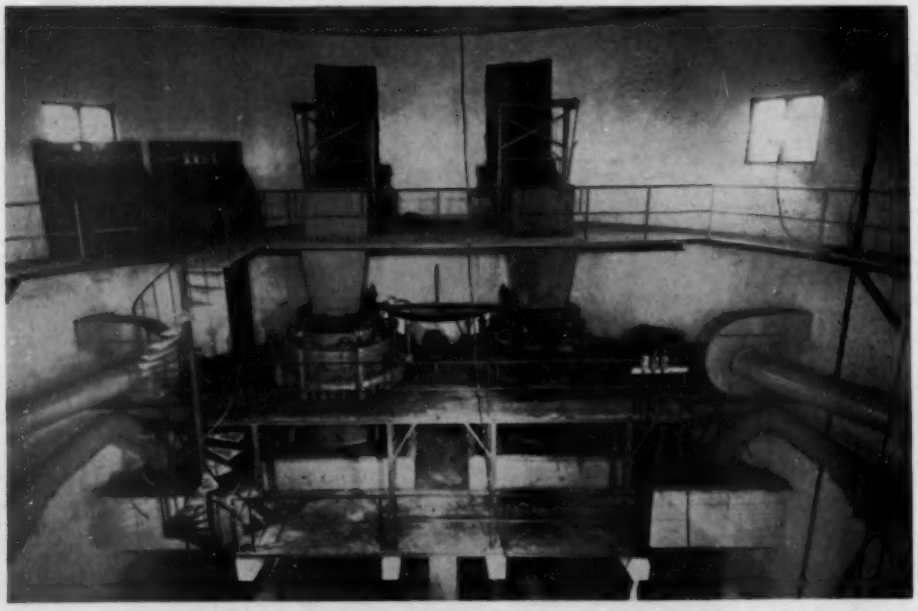
by T. Heikkinen and H. Tanner

IN 1950 studies concerning mining and milling of the approximately 17 million tons of ore remaining at Outokumpu revealed the surface facilities for economical treatment were inadequate. The two shafts would soon be too far from the mine workings. Moreover, in spite of several extensions, mill capacity was insufficient and recoveries were not satisfactory. Therefore it was decided in 1951 to sink a new shaft and to build a new mill and auxiliary surface buildings around the shaft.

The new shaft was sunk near the center of the remaining orebody, about 650 ft from the ore to the footwall side. This location placed the main part of the shaft as well as the crusher rooms and the ore bins around the lower end of the shaft in the firm and strong mica-schist.

Shaft sinking started in summer 1951 and construction of the surface plant in May 1953. At the end of 1954 the new plant began full capacity operation and ore treatment in the old plant ceased.

T. HEIKKINEN is Mill Superintendent and H. TANNER is Mine Superintendent, Outokumpu Co., Finland.



Two of the secondary Symons cone crushers are shown in the shaftplant. Others of same type are located in underground crushing plant.

The Keretti Shaft

The cross-section of the shaft is a rectangle, 8.75 x 32.81 ft, with six compartments: 1) Cage compartment with space for pipes and cables, 2) Counterweight compartment, 3) Manway compartment, 4) Skip A compartment, 5) Ventilation compartment, and 6) Skip B compartment. The shaft has sets at 10-ft intervals, using 10x10 and 8x10-in. impregnated timber. Guides are 8x8 in. About 328 ft of the upper part of the shaft that goes through serpentinite has been lined with concrete by using the pre-packt method.

Shaft depth is 1338 ft, with levels at 820, 935, and 1049 ft connected with the old workings of the mine. The 1049 level is below the orebody and is the main haulage level.

Underground Crushing and Ore-Bin System: Haulage of the broken ore on the 1049 level takes place in 4.6-cu yd Granby-type cars. There are 8 to 10 cars in a train. Ore cars are dumped straight into the jaws of a 47 x 59-in. single-toggle crusher set with 12-in. gape. This crusher replaces a grizzly, thus saving work and powder, and makes secondary blasting unnecessary.

Crushed ore goes to a 1500-ton bin, from which the ore is fed by vibrating feeders to two 24 x 35-in. jaw crushers. Ore is crushed to 4.7 in. and goes to a 3000-ton bin.

Both the underground bins are upright and have an elliptical cross-section, 23x29.5 ft. The longer axis of the ellipse is perpendicular to the schistosity of the rock. The walls of the bins have been rock-bolted with bolts of deformed structural steel. After the nuts are tightened, the holes are grouted so that the bolts will remain pre-stressed even if the nuts are worn out.

From the lowest 3000-ton bin ore is fed by vibrating feeders to two 39.4-in. belt conveyors which transfer it to the pockets of the 1312 level.

Hoisting: The ore is hoisted by an ASEA Koepe hoist mounted directly in the headframe which handles two bottom-dump skips in balance.

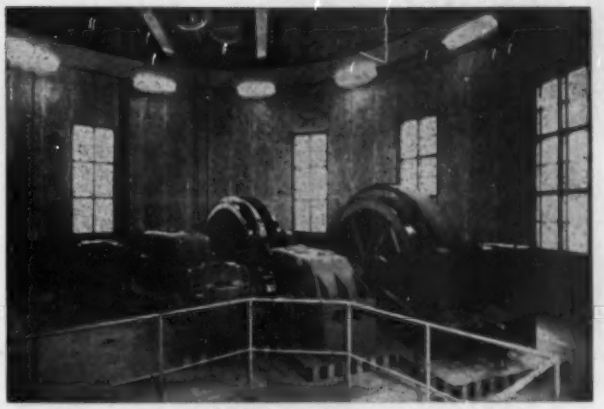
Data on the automatic hoist:

Pulley	9.84 ft diam
Ropes	2x32 mm
Hoisting speed	23 fps
Winding distance	1476 ft
Weight of load	5.5 tons
Winding motor	650-hp, 50-cycle ac
Manner of operation	manual, push button, or automatic
Hoisting capacity	230 tph

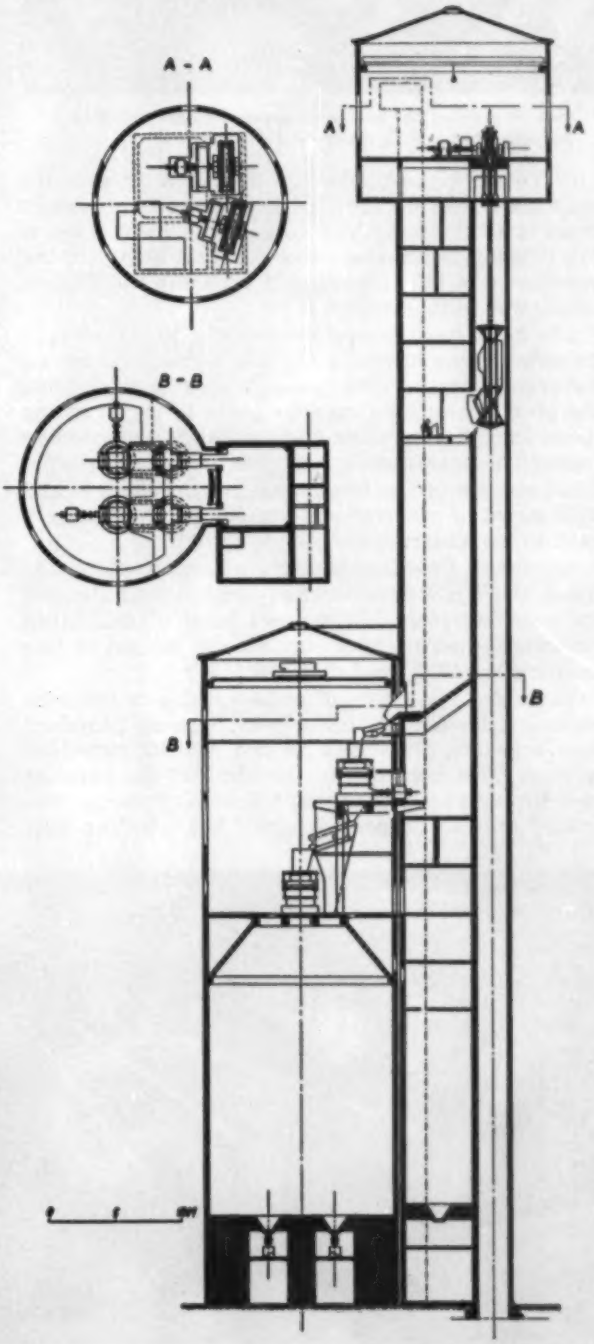
The measuring pockets are self-weighing. The vibrating feeder and the conveyor belt stop after 5.5 tons of ore has been fed to the pocket. The measuring pocket empties its contents into the skip right when the skip reaches its loading position, and at the same time the other skip unloads to the bin in the headframe. After the measuring pocket has emptied its contents and the gate is closed, hoisting starts again automatically and the feeder and the belt start to operate.

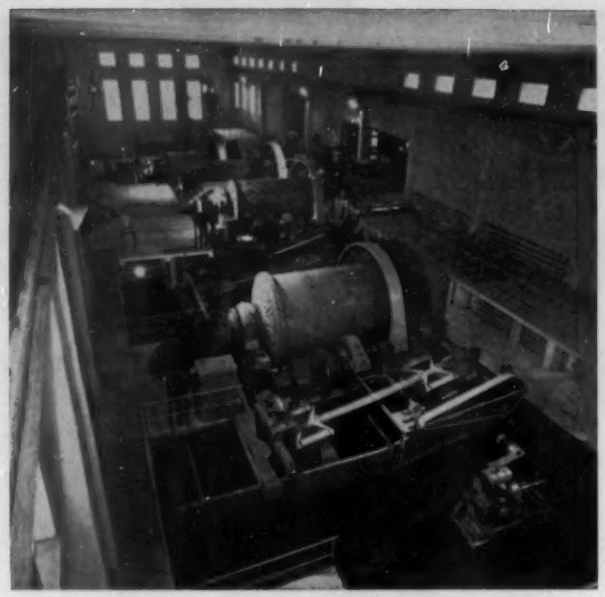
Push-button operation of the hoist can take place at the filling station or the manual operation at the unloading station. This is necessary especially during the inspection of the shaft and ropes. There is another similar hoist with a 250-hp motor for a cage using counterweight.

Head Frame: The head frame is of reinforced concrete construction cast by means of sliding molds.



ASEA Koepe hoist for Keretti shaft is located at top of headframe. Section shows head frame and secondary crushing plant at the Keretti shaft.





View of grinding bay of Keretti plant shows the two 6x12-ft rod mills and two 9x12-ft ball mills.

The Tower cross-section is 26.2x32.8 ft and the cylindrical top of the tower containing the hoist room is 46 ft diam. The floor of the hoist room is 275 ft above the surface and the total height of the headframe is 315 ft making it probably the highest headframe in the world.

The hoist room is equipped with a 10-ton electric traveling crane having a circular track. Its hoisting distance is 301 ft. This crane is used in assembling the hoist, in hoisting crusher parts to the crushing room, in replacing skips or ropes, and in shortening ropes. The headframe ore bin has 1000-ton capacity. Total volume of the headframe is 315,000 cu ft and 2350 cu yd of concrete and 530,000 lb of steel were used in its construction.

Secondary Crushing House: Adjacent to the headframe there is a 6000-ton fine-ore bin, and above it the crushing plant. It too was built of reinforced concrete by means of sliding molds. Height of this building is 148 ft, and diam 46 ft.

There are two series of crushers. Ore is fed with vibrating feeders to the 5½-ft Symons Standard cone crushers, then goes to the 5x10-ft two-deck screens. The fines fall to the bin and the oversize goes through 5½-ft Symons SH cone crushers. Secondary crusher capacity is about 200 tph. The dust collection system comprises a cyclone which separates sand out of the dust-laden exhaust air.

The crushing house is so designed that pieces of ore 1 to 2-in. diam can be separated from the crushed ore for possible use for ore pebble grinding. There is a 100-ton silo in the lower part of the head frame for these grinding pebbles. The headframe also houses transformers and switchgear for serving crushers and hoists.

Owing to the experience with the earlier crushing houses at Outokumpu the new Keretti crushing plant was designed so that conveyors between different stages of crushing were not necessary. Ore flows through the crushing process by gravity. The amount of machinery was reduced to a minimum and the whole plant made more reliable in operation and more easily serviceable. But, avoiding conveyors in the crushing process has considerably increased the height of the headframe. Total volume of the crushing house with the ore silo is about 50,000 cu ft and 1850 cu yd of concrete and 210,000 lb of steel were used in the building.

The Mill at the Keretti

The mill building directly adjoins the headframe and crushing house. Total volume of the mill building is 1.65 million cu ft. The wall construction, from the inside out, is: 5 in. of reinforced concrete, 5 in. of insulation board, 3 in. of air space, and 6 in. of concrete brick, for a total thickness of about 19 in. The ceiling is built of prefabricated concrete parts.

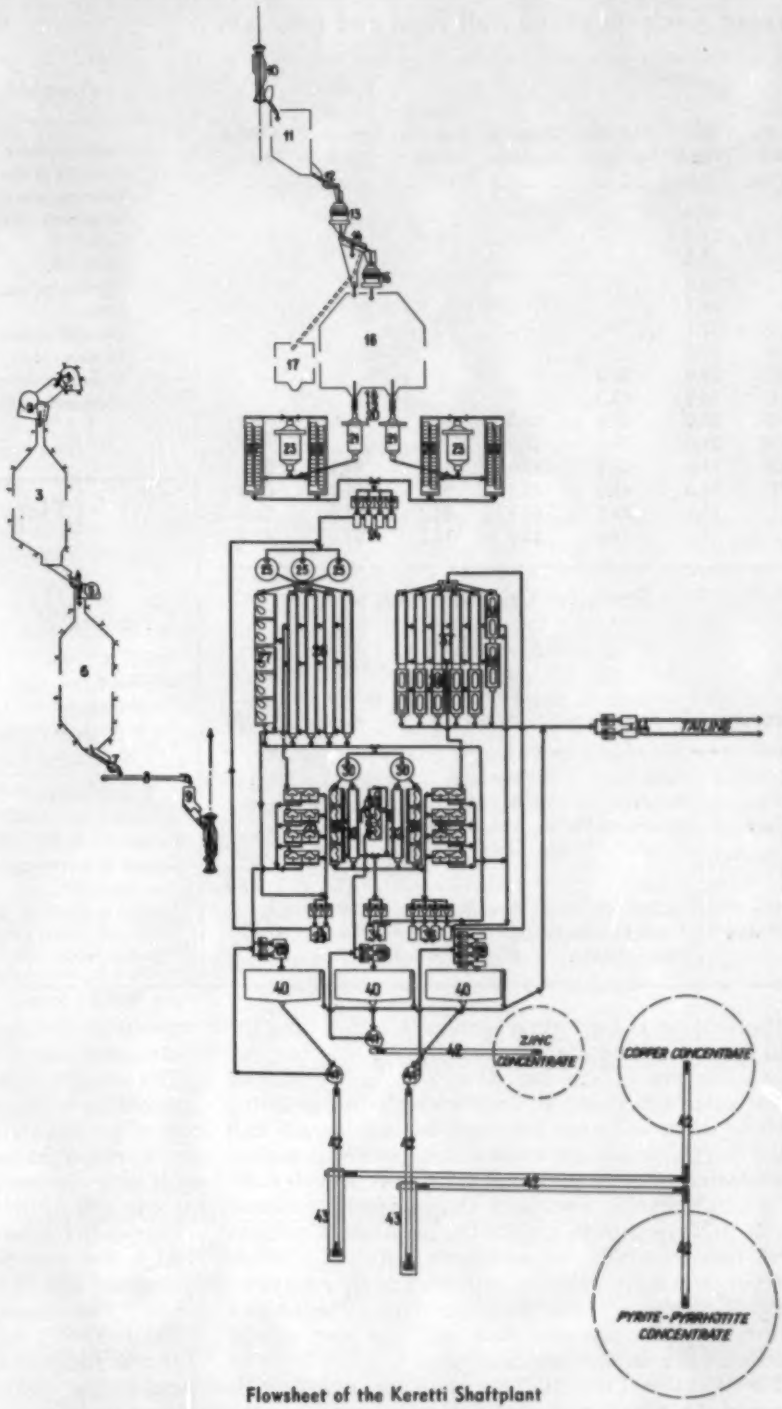
Grinding: From the fine-ore bin the ore is drawn out through eight chutes and fed by belt feeders to two conveyors equipped with automatic weighers, which transfer it to the rod mills. The two 6x12-ft rod mills operate at 24 rpm (73 pct critical) in open circuit. End liners and plates of the shell liners are chrome-steel and lifter bars of manganese-steel. The rods are 3 in. and rod consumption is 1.2 lb per ton.

Rod mill discharge flows to four 8x30-ft rake classifiers. The classifiers sand product is raked to two 9x12-ft ball mills, each operating in closed circuit with two classifiers. Ball mill speed is 20 rpm (75 pct of critical). Ball mill liners are chrome-steel, and in the shell liners every other bar is higher and works as a lifter. The liner bars are built up of three parts with identical lengths wedged to the shell with two circumferential rings. The balls are 1¼-in. diam cast iron and consumption is about 1.1 lb per ton.

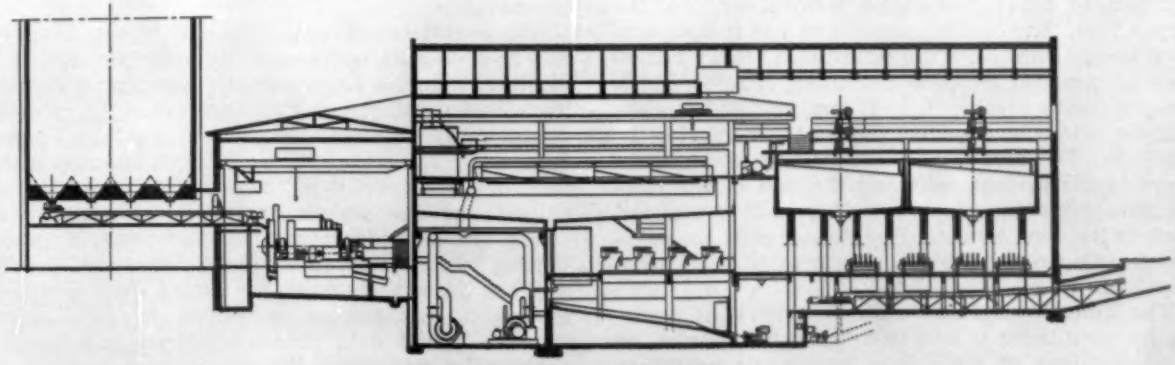
Photograph shows open arrangement copper flotation section of Keretti. These machines are located on an upper floor.

LEGEND

1. 123.5-cu ft Granby-type mine car
2. Single-toggle crusher, 47x59-in.
3. Ore bin, 1500 tons
4. 2 vibrating feeders
5. 2 jaw crushers, 24x35-in.
6. Ore bin, 3000 tons
7. 2 vibrating feeders
8. 2 conveyor belts, 39.4 in.
9. 2 measuring pockets, 5.5 tons
10. 2 bottom dump skips, 5.5 tons
11. Ore bin, 1000 tons
12. 2 vibrating feeders
13. 2 5½-ft Symons Std. cone crushers
14. 2 vibrating screens, 5x10 ft
15. 2 5½-ft Symons SH cone crushers
16. Ore bin, 6000 tons
17. Bin for ore pebbles
18. 8 belt feeders
19. 2 conveyor weighers
20. 2 belt conveyors, 24 in. wide
21. 2 rod mills, 6x12 ft
22. 4 rake classifiers, 96 in. x 30 ft
23. 2 ball mills, 9x12 ft
24. 4 centrifugal sand pumps, 4 in.
25. 3 conditioners, 9.8x13 ft
26. 4 pneumatic flotation machines, 43 in. x 54 ft
27. 5 2-cell flotation machines, 60x60 in.
28. 4 4-cell flotation machines, 43x43 in.
29. 2 centrifugal sand pumps, 6 in.
30. 2 conditioners, 9.8x13 ft
31. 8 2-cell flotations machines, 43x43 in.
32. 2 pneumatic flotation machines, 43 in. x 30 ft
33. 6-cell flotation machine, 43x43 in.
34. 2 centrifugal sand pumps, 4 in.
35. 4 centrifugal sand pumps, 4 in.
36. 7 4-cell flotation machines, 56x56 in.
37. 5 pneumatic flotation machines, 43 in. x 30 ft
38. 4 4-cell flotation machines, 43x43 in.
39. 8 centrifugal sand pumps, 4 in.
40. 6 thickeners, 33x13 ft
41. 10 4-disk filters, 6-ft diam
42. 8 belt conveyors, 17 in. wide
43. 3 rotary driers, 5.6x32.8 ft
44. 2 centrifugal sand pumps, 8 in.



Flowsheet of the Keretti Shaftplant



Section through Keretti Mill

Screen Analyses of the Mill Feed and Products

Screen Size, mm	Mill Head	Rod Mill Discharge	Classifier Discharge	Copper Concentrate	Pyrite-Pyrrhotite Concentrate	Flotation Tailing
20	89.4					
15	77.7					
10	63.0					
5	52.6					
3	44.2					
1.5	37.1					
1.0	33.2					
0.6	28.9	94.0				
0.5	26.4	87.3				
0.38	24.0	79.0	99.3			99.0
0.30	21.0	67.6	97.0			95.3
0.20	17.5	54.3	92.0	99.3	99.3	84.3
0.15	14.0	41.0	82.7	95.3	95.3	69.0
0.10	10.9	29.3	69.3	84.7	83.0	53.0
0.075	9.2	23.0	56.0	74.3	68.0	42.3

Reagent Consumption

Circuit	Reagents	Points of Addition	Consumption lb per ton milled	pH
Copper	CaO	Rod Mills	3.3	11.5
	NaCN	Rod Mills	0.03	
	K-amyl xanthate	Conditioners, Cells	0.24	
	Flotol (Frother)	Conditioners	0.04	
Pyrite-pyrrhotite	H_2SO_4	Pump boxes	21.4	5.7
	$CuSO_4$	Pump boxes	0.51	
	K-ethyl xanthate	Cells	0.64	
	Flotol (Frother)	Where required	0.01	

Power Consumption

Point of Use	Kwh per ton
Underground crushing	0.4
Hoisting of the ore	2.3
Hoisting of men	0.4
Secondary crushing	1.7
Grinding	10.8
Flotation	16.9
Thickening and filtering	3.5
Drying	0.7
Stockpiling and loading	0.2
Pumping of tailings	0.5
Water pumping	0.8
Illumination, etc.	0.3
Total	38.5

Flotation Data and Recovery

Product	Pct, Wt	Cu	Zn	S	Fe	Insol.
Mill head	100	3.25	1.0	22.4	23.7	44.0
Copper concentrate	13	23.15	1.6	37.1	33.2	4.4
Pyrite-pyrrhotite conc.	38	0.35	1.7	42.1	45.7	7.2
Tailing	49	0.22	0.3	3.2	4.1	83.0

Recoveries	Pct
Copper in copper concentrate	92.6
Copper in copper concentrate and in pyrite-pyrrhotite concentrate	96.7
Sulphur in pyrite-pyrrhotite concentrate	71.4
Sulphur in copper concentrate and in pyrite-pyrrhotite concentrate	93.0

Capacity of the grinding section is 80 tph, and the mill has been dimensioned accordingly. The rod and ball mills are of the overflow type and equipped with roller bearings. In both ends of the grinding section there is room reserved for additional ball mills which would be needed for pebble grinding.

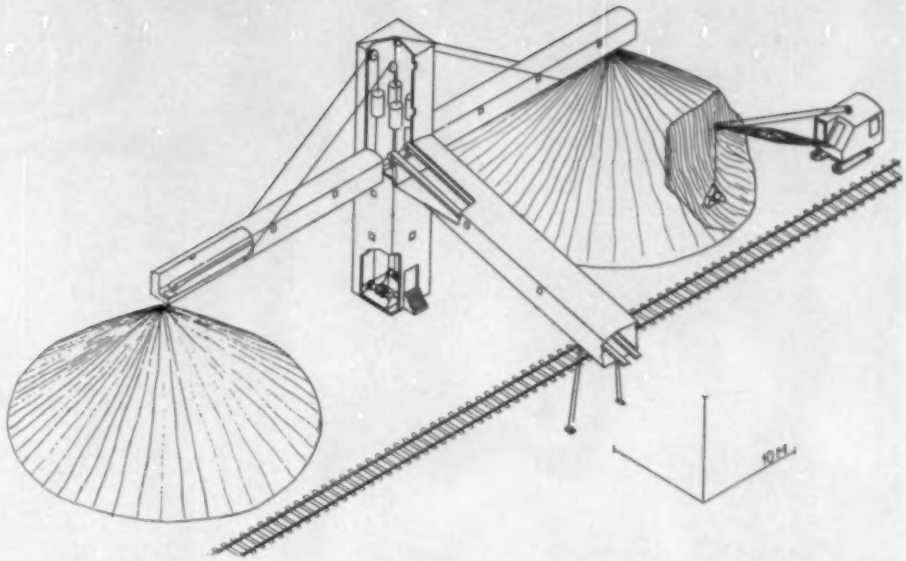
Flotation: This now takes place in two circuits. First chalcopyrite and then the sulphide minerals pyrite and pyrrhotite are floated together. Machines have been reserved for sphalerite flotation but are not yet in use. Rougher flotation of copper concentrate is carried out on the upper floor. The copper concentrate cleaner machines and the zinc circuit machines are on the ground floor.

The Copper Circuit: The classifier overflow is pumped to three pneumatic conditioners on the upper floor. The conditioners are of 9.84 ft diam and 13 ft deep. Pulp from the conditioners flows to five parallel rougher flotation machines, four of which are pneumatic machines, 59 ft long and 43 in. wide, and the fifth a bank of five duplex mechanical cells, 60x60 in. The first part of the rougher concentrate flows to the cleaner cells and the rest of the concentrate joins the cleaner tailing and is pumped back to the conditioners. The cleaner cells are composed of four parallel banks of four mechanical cells, 43x43 in.

The Zinc Circuit: There are two 10x13-ft pneumatic conditioners and four parallel banks of roughers, two of which are pneumatic machines 29.5 ft long and 43 in. wide and the other two composed of four duplex mechanical cells, 43x43 in. For cleaning there are six 43x43-in. mechanical cells. The copper circuit tailing flows through the conditioners to the zinc circuit, and middling is pumped back to the conditioners.

Pyrite-Pyrrhotite Circuit: Rougher flotation takes place in six parallel banks of cells, five of which are composed of pneumatic machines 29.5 ft long, and a four-cell mechanical machine, 56x56 in. The sixth bank has two four-cell mechanical machines. The cleaners are of the same type as for the copper circuit. The concentrate from the first part of the roughers is a part of the final concentrate; the rest of the rougher concentrate is cleaned and the tailing of the cleaners is returned to the beginning of the circuit.

The final flotation tailing flows by gravity through 525 ft of 9-in. asbestos cement pressure pipe at a grade of 2 pct to an intermediate pumping station. Two Hydroseal pumps, another being in reserve, pump to the tailings area, which is 0.5 to 1.0 km from the pump station. The rest of the pumps in the mill are 4-in. or 6-in. centrifugal pumps, with chilled cast iron wearing parts. Reinforced rubber tubes are considerably used as pressure pipes. Taking into consideration the fact that the Keretti mill has been in operation for such a short period—the plant was started in November 1954—some changes in the data presented above can be expected. In designing the building flexibility to changes caused by future developments was con-



Isometric drawing shows layout of stockpiling and loading installation. Reclaiming is by power shovel to cars on siding shown.

sidered. Also, the parallel banks of different type cells in the circuits show that continuous testing is carried on.

Thickening and Filtering: The flotation concentrates are pumped to six 33x13-ft thickeners on the upper floor of the mill; two are for copper concentrate, one for zinc concentrate, and three for pyrite-pyrrhotite concentrate. From the thickeners the underflow goes by gravity to 6-ft diam, 4-disk filters on the ground floor. Three filters are for copper concentrate, one for zinc concentrate, and six for pyrite-pyrrhotite concentrate. After filtering the moisture content of the concentrates is 10 to 11 pct.

Drying, Stockpiling, and Loading: The copper concentrate and the pyrite-pyrrhotite concentrate are dried in 5.6x32.8-ft cylindrical rotary driers. There is one drier for the copper concentrate and two driers for the pyrite-pyrrhotite concentrate, and the driers and the central heating plant of the surface buildings at Keretti have a combined furnace. Firewood is used as fuel, but the furnace is so designed that it can also be heated with oil. The dried concentrates contain 4 to 6 pct moisture. Concentrates are transferred to the driers and then to the open storage area by belt conveyor. Power shovels with clamshells load concentrates into railroad cars.

Power: A 45,000-v line from the nationwide network of power companies transmits power to the Outokumpu mine. Two 4000-kva transformers step plant power down to 3000-v, then eleven 3000/380-v transformers in different parts of the plant supply the 380-v motors. Motors on the mine hoists use 3000 v. Total power consumption is 38.5 kwh per ton of ore treated.

Water Supply: The plant supply is pumped from a nearby lake through a 492-ft pipeline. There is a circumferential water reservoir having a capacity of 53,000 gal in the space between the secondary crushers and the fine-ore bin. The water consumption is about 1000 gal per ton of ore.

Change House: This is another building adjacent to the headframe. There is space for 350 men. As a specialty, next to the men's wash room there is a Finnish Sauna, which stands high in the miners' favor. Dining rooms for the surface workers are also in this building. Shops and stockrooms are in a combined building near the headframe and the mill.

Acknowledgments: The authors wish to thank P. Bryk, general manager of the Outokumpu Co., for permission to publish these papers.

The Outokumpu Co., Finland

MINES

Outokumpu Mine

Ore discovered 1910
Content 3.7% Cu, 24.7% S, 0.2% Co
Operation started 1913
Production 1927 100,000 tons
1936 360,000 "
1942 600,000 "

Orijärvi Mine

Ore discovered 1757
Content 0.6% Cu, 2.5% Zn, 0.8% Pb
Operation started 1758
Purchased by Outokumpu Co. 1945
Production 1953 45,000 tons
Idle since 1954

Ylöjärvi Mine

Ore discovered 1938
Content 1.00% Cu, 1.15% WO_3
Operation started 1943
Production 1954 138,000 tons

Aijala Mine

Ore discovered 1946
Content 1.8% Cu, 17.4% S
Operation started 1949
Production 1954 122,000 tons

Metsämonttu Mine

Ore discovered 1948
Content 4.6% Zn, 16.0% S
Operation started 1952
Production 1954 83,000 tons

Nivala Mine

Ore discovered 1937
Content 1.81% Ni, 0.43% Cu
Operation started 1941
Production 1953 77,000 tons
Shut down 1954

Vihanti Mine

Ore discovered 1950
Content 12.0% Zn, 0.8% Cu, 0.5% Pb
Operation started 1954
Est. yearly production 300,000 tons

METALLURGICAL PLANTS

Harjavalta Copper Smelter

Operation started 1936
Production 1954 21,000 tons of copper anodes

Pori Electrolytic Plant

Operation started 1941

Pori Rolling Mill and Extrusion Plant

Operation started 1940

Total Production of Outokumpu Co. in 1954

Ore mined 1,004,500 tons
Electrolytic copper 21,000 tons
Pyrite-pyrrhotite concentrate 250,000 tons
Zinc concentrate 9,100 tons
Gold 8000 oz
Silver 225,000 oz

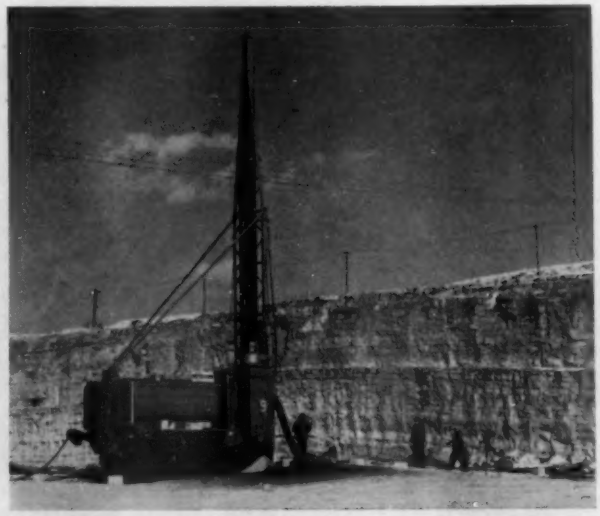
Marmora: *Bethlehem Beneficiates Open Pit Ore, Pelletizes Concentrates, at New Iron Producer*

BETHLEHEM Steel Co. has just brought an all-new iron ore mine into production at Marmora, Canada, about 120 miles east of Toronto. High grade pellets produced at the mine from open-pit magnetite ore travel 64 miles by rail to the port at Picton, then go by Lake boat to help supply Bethlehem's Lackawanna, N. Y., plant. At full production about half a million tons of pellets a year will be shipped, and mining will be at a scale of more than a million tons per year of ore.

Aeromagnetic surveys carried out in 1949 by the Ontario Dept. of Mines and the Canadian Geological Survey revealed an anomaly that interested Bethlehem geologists. By 1951 the company had put down some 40 diamond drillholes ranging from 460 to 1800 ft to block out the magnetite replacement deposit which lies in pre-Cambrian limestone below about 130 ft of Paleozoic limestone. The orebody, roughly 2100 ft long and up to 400 ft wide, averages about 37 pct iron, too low for direct shipment. Not only construction of concentrating and pelletizing facilities, but 20 million tons of stripping lay ahead before production could start.

Twenty Million Tons of Stripping

In 1952 stripping began at a rate that approached ¾ million tons per month from the 1200x2600-ft pit area. During stripping operations, drilling was with two electric 6¾-in. rotary drills. These have since been replaced for mining operations by three percussion drills. The 53-ft holes, spaced 25 ft with 25-ft burden, were drilled at rates of 20 to 25 ft per hr. Bit life averaged 1300 ft and the best bit went 3200 ft. Primary blasting used 5x16-in. cartridges of 50 and 70 pct dynamite to break 4.5 tons of limestone per lb of explosive. Primacord and millisecond delays were used. Zero delays on the center two holes of a row were followed progressively by delays up to eight. Fragmentation from this practice permitted a 6-yd bucket to handle almost 100 pct of material.



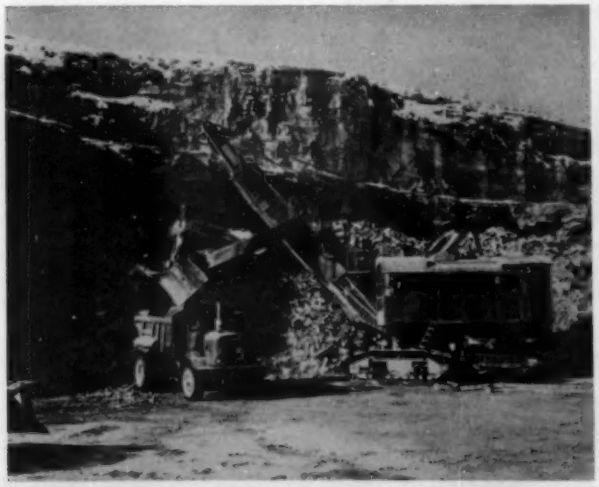
Three percussion drills operate on the 45-ft benches. Drills use 6-in. tungsten carbide insert bits to *make hole* at more than 6 ft per hr.

OPEN PIT: (Opposite Page) At end of primary stripping and start of ore production first ore bench can be seen at center left. Inclined skipway, crushing plant, and mill are at far left. Note cut for truck entry in distance. Pit surface is smooth enough to drive a passenger car over.

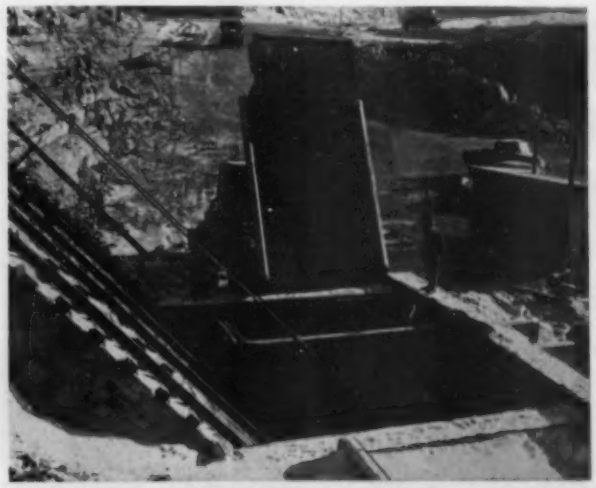
PLANT BUILDINGS: (Above) Pit shows at right rear, headframe at near pit edge, crushing plant at center, and mill and pelletizing plant at left. Buildings forming square in foreground are main shops, garages, offices, warehouse, and welfare building. Stripping dumps form background.

During the stripping program three 6-yd electric shovels loaded a fleet of 21 dump trucks which are also used for ore mining. The 22-ton diesel trucks have 300-hp engines, torque converters, semiautomatic transmissions, heated dump boxes, and other winter equipment. Box lining was ½x4-in. abrasive-resistant steel strip on 8-in. centers. Truck fleet availability was above 70 pct, counting all time loss, maintenance, etc. Stripping, carried out around the clock, was not stopped by heavy snow, Hurricane Hazel, or low temperatures—but was hampered by fog on one or two occasions.

With completion of stripping all equipment was shifted to ore production except the rotary drills. For ore, three percussion drills with 6-in. tungsten carbide bits are now working the 45-ft benches. Shovel dippers were changed from 6 to 4½ yd for ore, and trucks hauling ore dump directly into bal-



Electric shovels with 4½-yd dippers load ore. Same shovels used 6-yd dippers for stripping job. Some of the 22-ton diesel trucks have seen over a million miles in service but have received careful maintenance.



Trucks dump into 22-ton skips at foot of incline. At top of 240-ft, 45° incline the balanced pair of skips dump into a 48-in. gyratory primary crusher. Layout and inclined skipway result in short ore haul at little or no grade.

Photograph taken during construction shows the secondary gyratory crusher and tertiary hydrocone crusher. Magnetic pulleys cob waste between primary and secondary, and again between secondary and tertiary crushers.

Two primary rod mills are at right center in this view of concentrator building. One ball mill is in foreground, other in distance. Final magnetic separators are on floor below, seen at left center.

anced 22-ton skips on a 45° incline going up to the pit rim. Eventually mining will remove about 17 million tons of ore together with another 14 million tons of waste in reaching planned pit depth of 500 ft.

Crushing and Concentration

In normal operation about 4200 tpd will be hoisted up the incline and dumped directly into a 48-in. gyratory crusher in the headframe. Primary crusher product at −5½ in. goes to a stockpile with tunnel reclaiming. A 5½-ft secondary gyratory to reduce ore −2-in. is followed by a tertiary hydrocone crusher yielding final crusher product at −⅜. Barren material is scalped by magnetic pulleys between primary and secondary crushers and also between the secondary and tertiary crushing stages.

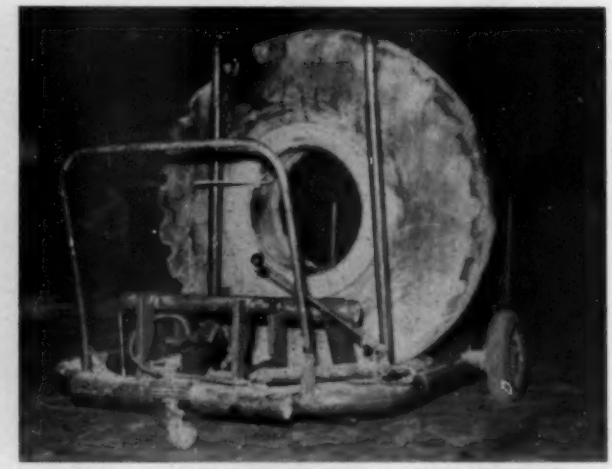
Mill feed goes to two 8x12-ft rod mills in open circuit, then to two 10½x10-ft ball mills in closed circuit with cyclone classifiers. High-intensity drum separators in the circuit cob coarse nonmagnetic material. Cyclone overflow, −100 mesh, goes to two 3-drum magnetic separators that make final concentrate.

Concentrate is pumped to the pelletizing plant where it is mixed with fine anthracite and thickened, then goes to one of four parallel sections, each equipped with a six-disk, 6-ft diam filter. Filtered concentrate at about 10 pct moisture has bentonite added to it for better pellet quality and is charged to one of four 8x16½-ft balling drums. Each balling drum feeds a shaft furnace. The oil-fired vertical shaft furnaces have approximately 75 sq ft of grate area, divided into two 6x6-ft compartments. Green pellets are fed to the furnaces by an oscillating belt conveyor. Furnace staging results in slow drying and preheating before temperature rises to about 1250°C for baking. Plant capacity is about 1750 tpd of pellets. After cooling and screening pellets are loaded for rail shipment to Picton, 64 miles away.

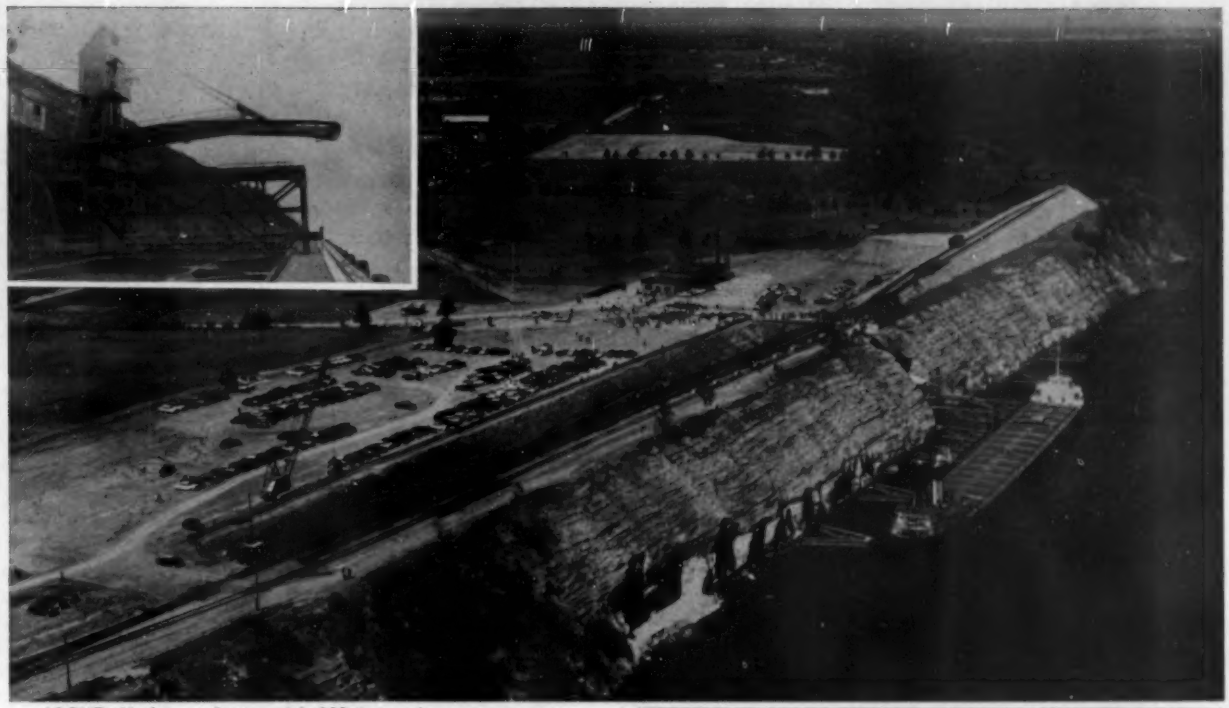
Construction at Marmora for main buildings is steel with insulated asbestos roofing and siding. The principal shop is a U-shaped single story structure 50x260-ft with two 40x120-ft wings. This building houses the machine shop, carpenter shop, truck service shop, and garage. The general office building houses the engineering offices and a dispensary and

Safety, Maintenance, and Housekeeping Receive Close Attention

Safety signal device indicated by arrow has plate that comes down in front driver's windshield when box is in raised position so that driver will not pull away before box is down.



This handy rack for truck tires has hydraulic controls to move, lift, and tilt tire. Rack, designed and built by mine personnel, shows close attention paid to safety.



ABOVE: Harbor at Picton with 800-ft trestle over a storage pit into which the railroad cars dump pellets. A system of underground conveyors feeds pellets to retractable loading tower (see inset). RIGHT: This photograph shows the loading tower in farthest position out with boom lowered. BELOW: A closer view of storage pit and trestle shows part of first boatload of pellets. One of the 25 chutes in roof of conveyor tunnel is exposed.

the welfare building provides showers and toilet facilities. All of the service buildings are interconnected.

Loading Installation at Picton

On arrival at Picton the railroad cars pass over an 800-ft trestle built above a 30 to 40-ft deep storage pit. The pit or trench is excavated from solid rock. Live storage for 25,000 tons is augmented by 330,000 tons of surface storage space in order to provide adequate winter capacity when Lake shipping closes. Crane handling is used between pit and ground storage.

Pellets flow from the storage pit through 25 chutes in the roof of a recovery tunnel to a conveyor running the full length of the pit. The 42-in. belt has a capacity of 2000 tph. It discharges to a second conveyor running at 90° to it that goes out through an adit to a point in the cliff face above the water. This conveyor in turn discharges to a third conveyor mounted on a retractable loading tower.

The retractable tower is designed for a shuttle travel of 54 ft perpendicular to the dock fender in order to suit ships of different beams. The conveyor boom can also be raised or lowered to serve different water levels and reduce the free fall of the pellets. A 12,000-ton ore carrier can be loaded in about 9 hr.

The 1200-ft dock is supported on steel piling with a 240-ft loading section. Accommodation is provided for the largest Lake carrier and the bay alongside the dock has been dredged 27 ft below mean low water level.

Shipping will be carried out about seven months a year, but storage will continue throughout the year, as will mine and mill operation. Offices, welfare facilities, a shop, and customs office are provided at the port.

INTERNATIONAL MINERAL TRADE SERIES

Thirteen Rules Governing Trade in Metal Raw Materials

by John D. Ridge

THE quantities and destinations of the metallic ores and concentrates and partially or fully refined metals in international trade result from the interaction of many factors, of which geographic location is only one. How far the processes of concentration and refining are to be carried in the country in which the mining is done and what dictates the destinations to which the more or less completely processed raw materials will move are determined not only by present-day geologic, political, and economic conditions, but also by the patterns set up by these same conditions as they obtained in the past.

The first generalization that can be made regarding trade in metal raw materials—one that affects the form in which the material is transported, rather than the patterns followed by that trade—is that *concentration is carried out for all low grade ores, nonferrous or ferrous, in the country in which they originate.* **(Rule 1.)** Economic considerations alone almost always require that this be done; only high grade iron, manganese, and chromite ores can be shipped as they are mined.

After beneficiation, the next decision to be made is the site at which the necessary smelting and refining are to be done. Any mining company wants to make profits on as many operations as its financial resources will permit and this attitude favors the conduct of smelting and refining in the mining country unless such facilities are already operated by the company in question in another area to which the concentrates can be readily shipped. Of course, only a sizable organization, which has acquired the necessary capital resources in one way or another, can build the required plant in the producing country, and many properties continue to send their concentrates abroad because they cannot, at least at present, afford their own smelting and refining facilities. It can, then, be generally said that *mining companies of large size and of domestic ownership will carry processing through more stages at home than will companies of small size or of foreign ownership.* **(Rule 2.)**

In many mining countries, legal barriers have been set up to prevent the export of concentrates. This is done, of course, to increase the revenue accruing to the nations in which the mineral raw materials were mined and perhaps to aid in building up its industrial plant. In addition to taxes that are levied on the materials in question no matter where they are smelted, taxes often are placed directly on exports. When such taxes are heaviest on the least processed mineral materials an added incentive is provided for domestic smelting and refining. Thus, it is apparent that *the stage of processing of any metal raw material entering world trade will tend to be the more advanced, the greater the tax penalties assessed against concentrates and partly processed materials leaving the country of origin.* **(Rule 3.)**

Still another factor that helps to determine the number of processing steps through which a metal raw material passes before it leaves its country of origin is the percentage of metal in the concentrate. The higher the metal content, the less unwanted material must be transported. From this can be derived still another general rule of such trade—*the smaller the quantity of material to be eliminated from concentrates in the smelting process, the more likely such concentrates are to be sent abroad for smelting and refining.* **(Rule 4.)** Thus, in the average case, lead concentrates are more likely to be shipped to an industrially advanced area for final processing than are those of copper because of the much higher percentage of lead in the average lead concentrate than of copper in copper concentrates. This rule is not without important exceptions, however, caused by the interaction of other mineral-economic factors. The high lead content of lead concentrates would suggest that there would be little compulsion for lead smelting to take place in the mining countries. Actually, only about 27 pct of the lead entering international trade is shipped as concentrate. For example, essentially all lead ore mined in Mexico is smelted in that country. This is done principally because: 1) the smelting process is a relatively simple one that can be readily adapted to a given input tonnage and can be carried out largely by cheap, semiskilled labor and further 2) the Mexican tax structure favors domestic smelting as opposed to concentrate export. The second reason has already been expressed as Rule 3. The first factor indicates that *the greater the flexibility and simplicity of a smelting process, the more likely it is to be important in a mining country producing the raw material concerned.* **(Rule 5.)**

Historical Influences

Another exception, acting in opposition to Rule 4, is the shipment of Bolivian tin concentrates to the U. S. and the United Kingdom; these are quite low grade and much undesirable material is sent with them, so that domestic smelting would seem to be justified, if not demanded. The smelting process, however, is quite complex and has been and is beyond the capabilities of Bolivian capital and labor. Nor have smelters been built in Bolivia with foreign funds, largely because of the difficulties of attracting capital and trained personnel to that country. From this it follows that *the more unstable the political situation in a given mining country, the less processed will be the mineral raw materials shipped from it* **(Rule 6.)**, unless processing facilities were established in a prior period when the country was apparently stable. The large smelters in Malaya, for example, would never have been located there had the political climate been then as it is now.

Once such smelters as those to which Bolivian tin concentrates are sent have been built, they constitute an additional deterrent to the construction of similar plants in the mining country. These foreign

JOHN D. RIDGE is Assistant Dean, College of Mineral Industries, and Head of the Dept. of Mineral Economics, Pennsylvania State University, University Park, Pa. ROBERT C. BARWICK is a Graduate Assistant in Mineral Economics, Pennsylvania State University.

smelters usually can pay enough for concentrates that the additional profit to be made from smelting will often be too small to justify the cost of domestic smelters. It follows, therefore, that the greater *the modern processing capacity for a given metal raw material outside the countries that mine it, the more likely the material is to be smelted abroad* (**Rule 7.**)

Despite the exceptions to Rule 4 provided by lead and tin concentrates, zinc concentrates, which average nearly 60 pct zinc, perform much as that rule would suggest and 65 pct of the zinc moved in international trade is as concentrates. Zinc more nearly obeys the general rule because zinc smelter size is much less flexible than that of lead. The horizontal retort method of zinc smelting, to be efficient, must be carried out on a large scale, while a lead smelter is much more easily tailored to fit a given tonnage input and requires a much smaller capital investment. For example, Peru mined 98,000 tons of lead in 1952 and smelted 48,000 tons domestically, while it mined 122,000 tons of zinc in that year and smelted only 5,000 tons. On the other hand, Belgium, which mines essentially no lead or zinc, smelted 190,000 tons of zinc in 1952 but only 75,000 tons of lead—again demonstrating the greater international trade in concentrates of zinc than of lead.

At the beginning of mining operations in any country, operations usually will be on a relatively small scale in comparison with what may later be attained, and smelting and refining capacity will be lacking. The metal raw material concentrates produced at this stage will be largely shipped abroad for further processing, and smelting and refining will be initiated in the producing country if no corporately or financially connected smelter is available abroad. In addition, such facilities can be financed domestically only if the operation is sufficiently profitable and if the reserves are large. The general rule which can be derived is that *the newer a mining industry is in a given country, the less likely it is that metal raw materials will be smelted there.* (**Rule 8.**) The development of a smelting industry, however, need not lag far behind that of mining. In French Morocco where large scale mining is a relatively new industry all lead concentrates were exported in 1950, but by 1952 that country smelted nearly 40 pct of its lead concentrates. In Peru, where the mining industry has been long established, the amount of lead mined has increased considerably over the past few years without causing any corresponding increase in smelter capacity.

Export-Import Relationships

One of the most important factors affecting trade in metal raw materials was and is the possession of colonies by a metal raw material processing and using country. In the early days of large scale metal raw material exploitation, mining was both expanded in the home country and extended to its colonial possessions. The colonial country had little tendency and less power to control the rate of production or the destination of its raw materials. As the colonial nations achieved major degrees of political independence, however, they grew more and more anxious and able to determine how their resources were treated and the nations to which they were shipped. Few such countries have done much to overthrow established ownership, but they have taxed metal raw materials, often heavily, to obtain revenue; have established controls over sales, both as to quantity and purchaser; and in extreme cases actually have expropriated mineral properties. These political developments, however, while having a considerable effect on the degree of refining done in the mining country, have had much less effect on the ultimate destinations of the metal materials involved.

Such consistent export-import relations as still obtain between the United Kingdom and the Commonwealth countries, even though the political ties between them are far less firm than they once were, indicate that trade relationships established largely because of political control do not change greatly when that control is relaxed. Similarly economic necessity can be more important than damage done by political activity. Although the Bolivian Government has expropriated the tin properties of the international interests controlling them, Bolivian tin still goes to British smelters in essentially the same amounts that it did before the seizure. The former owners of the tin properties prefer to keep their smelters in operation and lose only the profits of mining rather than lose the profits from both operations. In general, then, it can be said that *an export-import relationship, once formed, is more profitable to continue than to break off unless the economic or political changes are drastic* (**Rule 9.**), as they would be, for instance, if a communist government were to take over an exporting country now outside the Iron Curtain. This trade pattern stability often continues even when the exporting country changes from concentrate export to shipping refined metal. Thus, although much of French Morocco's lead production is now domestically smelted, the bulk of Moroccan lead still goes to France.

Technological Level is Important

The past economic and industrial history of any country will do much to determine its position in international trade in metal raw materials, and another series of generalizations can be set forth which are at least guides in explaining the patterns followed by such trade. Briefly, these are: 1) *the earlier and more rapid the industrialization of any country the more complete will be the processing of metallic raw materials within its own borders* (**Rule 10.**); 2) *the older and more advanced the industrial civilization of a particular country, the greater will be its dependence on mineral imports, a dependence that increases the more rapidly the less well endowed the nation in question was in the beginning of its industrialization* (**Rule 11.**); 3) *the later a nation began to develop its industrial plant, the larger will be the number of countries from which it imports and the smaller the amount it will obtain from each* (**Rule 12.**); and 4) *in such a lately industrialized country the more intensive will have to be its development of its own resources, though these well may be economically less satisfactory than deposits of the same metals in other countries* (**Rule 13.**). The evidence for the validity of these four rules is made apparent in the commodity discussions.

It can be seen even from the few examples given, that these mineral-economic rules must be used in *combination* if the trade pattern of any one country for any one metal is properly to be explained. No one rule can supply the only reason for existence of any mine or processing plant, much less explain all the complexities of international trade in these substances. Each case must be analyzed individually, keeping in mind all the rules and their possible exceptions, if what happens is to be understood.

INTERNATIONAL MINERAL TRADE SERIES
Part V

World Trade in Copper Metal and Concentrates

by John D. Ridge and Robert C. Barwick

IN contrast to iron and most of the ferroalloys, the bulk of world trade in copper is carried out in copper-bearing material which has been through one or more stages of smelting and refining. Approximately ten times as much copper which has been refined in some degree moves in international trade as does copper in concentrates. Two-thirds of the copper in concentrates traded moves to the U. S. and Germany is the only other important recipient of this material with 17 pct of the total. (See Table VI.) Most of the copper traded in concentrate form is either copper in complex concentrates which must be given special metallurgical treatment or comes from relatively new or small ore fields where smelters have not been built because of lack of time or lack of sufficient ore. Because of its highly developed copper smelting and refining industry and its tremendous need for copper, the U. S. gets the major share of such ores. These ores come to the U. S. from all over the world, with Canada being the most important supplier in 1952 because of a strike in a Montreal refinery which forced concentrate export to the U. S.

Germany's need for copper is reflected in its importation of nearly 30,000 tons of copper in concentrates from many sources, although Cyprus, Chile, and Norway were that nation's largest suppliers. Norway's position as an exporter and importer of copper concentrates is the result of the refining of Falconbridge nickel ore at Kristiansand and the exporting of concentrates from northern Norwegian mines. It is possible that the South West African concentrates imported by Belgium are re-exported to Germany, but the long established zinc and lead refineries in Belgium may well treat these copper-bearing zinc-lead concentrates. The United Kingdom is only a very minor importer of concentrates, as is Sweden.

The amount of U. S. copper supplied by imports of metal in concentrates is less than the amount of refined metal exported, so the continuance of concentrate supplies is not vital to the national existence. Several of our concentrate sources would certainly be cut off from us in the event of war, so it is comforting to know that the situation is different for the metal.

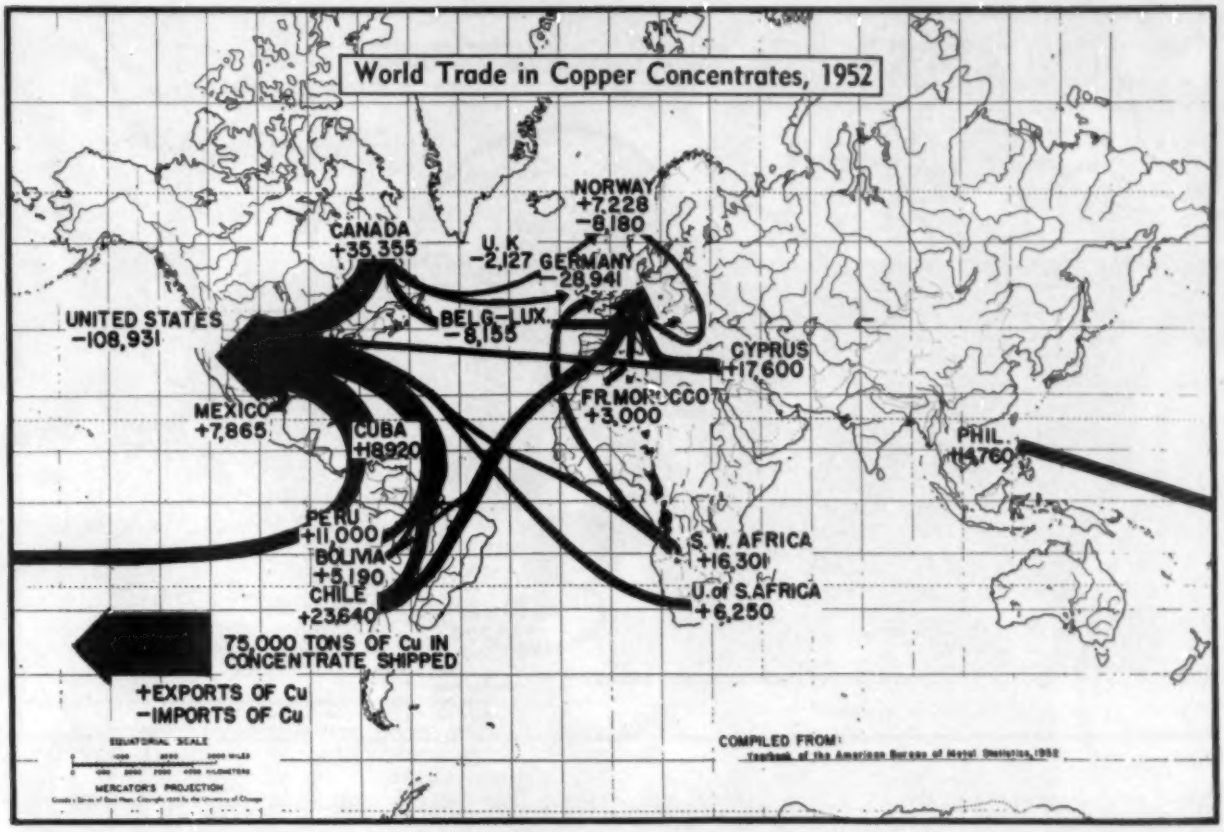
Copper in Metal Form

A glance at Table VII shows that the export-import pattern in copper metal is much more complex than that for copper in concentrates. In part this complexity is due to the large demand for the metal in a large number of countries, but another major cause is the re-export of copper metal, with or without additional refining, by many of the importing countries. Of the five countries listed as importing over 80,000 tons of copper metal in 1952, all, except France, exported enough to be listed among the major exporters. Each of these four countries, the U. S., the United Kingdom, Belgium-

Table VI. World Trade in Copper Concentrates,* Tons, 1952

Exporter	Total	Importer							
		U.S.	Germany	Norway	Belgium	U. K.	Sweden	Misc.	Europe
Canada	35,355	25,577	9,471	8,180	—	1,127	—	—	(9,800)
Chile	23,640	12,700	6,000	—	—	—	—	5,000	(6,000)
Cuba	18,920	18,920	—	—	—	—	—	—	
Cyprus	17,600	5,441	12,070	—	—	—	—	—	(12,070)
S.W. Africa	16,301	7,863***	300	—	8,155**	—	—	—	(8,455)
Philippines	14,760	14,760	—	—	—	—	—	—	—
Peru	11,000	8,859	—	—	—	—	—	2,100	—
Mexico	7,865	6,470	—	—	—	—	—	1,200	—
Norway	7,228	—	5,600	—	—	—	—	1,600	(5,600)
U. of S. A.	6,250	5,250	—	—	—	1,000	—	—	(1,000)
Bolivia	5,190	3,091	2,100	—	—	—	—		(2,100)
Fr. Morocco	3,000	—	2,400	—	—	—	600	—	(3,000)
Europe	(7,228)	—	5,600	—	—	—	—	—	(5,600)
	167,109	108,931	37,941	8,180	8,155	2,127	600	9,900	(48,025)
				1922					
N. Rhod.	74,000	13,000							61,000
Belg. Congo	46,000	—							46,000
Chile	38,000	9,000							29,000
Mexico	34,000	34,000							—
Canada	30,000	19,000							11,000
U. S.	29,000	—							29,000
Peru	21,000	21,000							—
India	6,000	—							6,000
Cyprus	3,000	—							3,000
	281,000	102,000							190,000

U. S. Production 1952 — 849,554.
* Includes ore concentrates and matte.
** Possibly re-exported to Germany.
*** Copper in lead-zinc concentrates.



Luxemburg, and Germany, imported more than it exported, but the excess of imports over exports of Belgium-Luxemburg and Germany was only 45,000 and 25,000 tons, respectively. Of the 1.3 million tons imported by these four countries, 400,000 were re-exported to a wide variety of countries. A more easily interpreted picture of trade in partly or fully processed copper could be made if the statistics available consistently indicated the degree of refining already given copper metal before it was shipped out of one country and into another. In this article, it has been found necessary to include ore, concentrates, and matte under copper in concentrates. All other material further processed is considered as copper metal.

The bulk of the copper metal that was imported into the U. S. in 1952 came from areas considerably removed from the possibility of interruption in the event of war. Chile, the largest supplier to the U.S., is well protected from potential enemy activity.

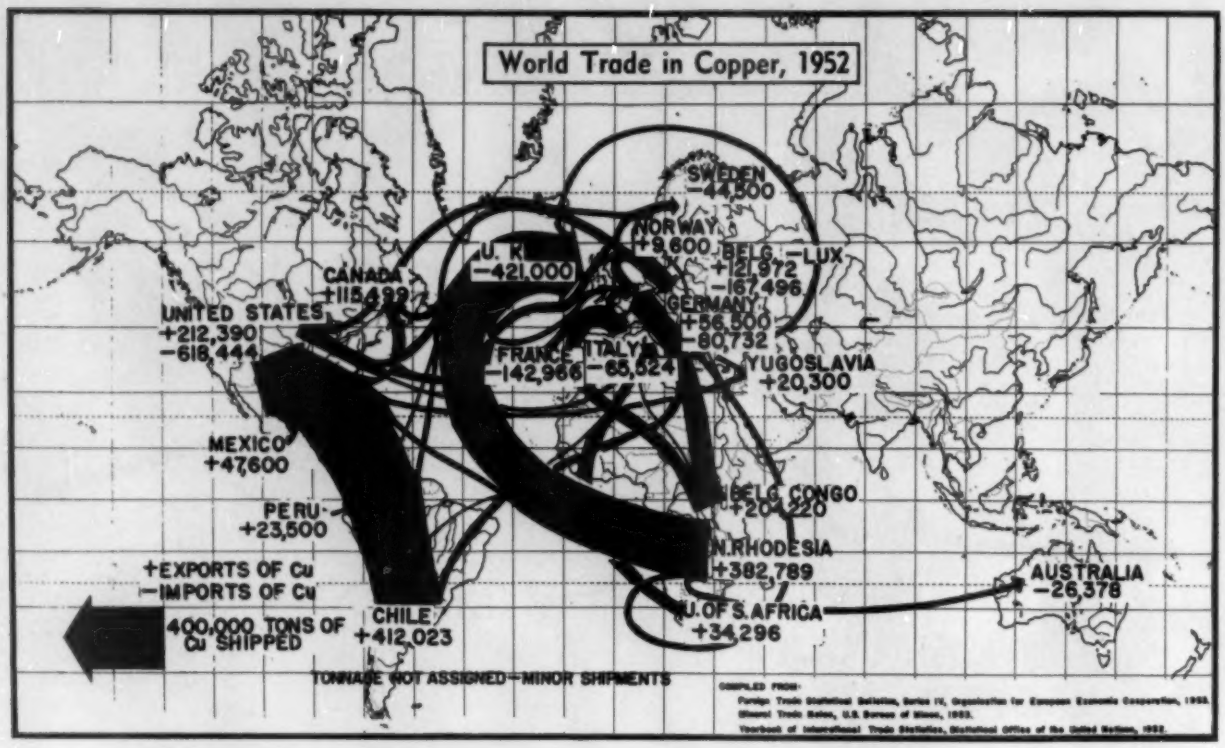
Table VII. World Trade in Copper Metal,* Tons, 1952

		Importer									
Exporter	**Total†**	**U. S.**	**U. K.**	**Belg.-Lux.**	**France**	**Germany**	**Italy**	**Sweden**	**Australia**	**Misc.**	**Europe**
Chile	412,023	349,969	5,450	—	—	27,700	15,985	3,919	—	9,000	(53,054)
N. Rhod.	382,789	28,225	269,630	19,993	3,497	7,952	4,650	14,012	10,585	24,245	(319,734)
U. S.	212,390	—	49,086	—	35,574	24,274	19,500	2,872	—	81,000	(131,306)
Belg. Congo	204,220	—	—	118,957	48,800	—	12,200	700	9,166	14,400	(180,657)
Belg.-Lux.	121,972	—	30,560	—	36,439	12,006	—	9,199	—	35,768	(86,204)
Canada	115,499	55,551	41,166	—	8,537	—	—	3,443	3,465	3,337	(53,146)
Germany	56,500	8,932	17,600	—	—	—	—	7,110	2,000	21,000	(24,710)
Mexico	47,600	42,723	—	—	—	—	1,770	—	—	3,100	(1,770)
U. of S.A.	34,296	—	4,480	5,039	8,416	—	11,419	—	—	5,000	(29,354)
Peru	23,500	1,700	—	20,000	—	—	—	1,800	—	—	(21,800)
Yugoslavia	20,300	14,800	1,000	—	1,700	2,800	—	—	—	—	(5,500)
Norway	9,600	—	—	—	—	3,000	—	—	—	6,600	(3,000)
U. K.	7,000	—	—	3,500	—	3,000	—	—	—	500	(6,500)
Africa	(621,305)	(28,225)	(274,110)	(143,989)	(60,713)	(7,952)	(28,269)	(14,712)	(19,751)	(43,500)	(329,745)
Europe	(215,372)	(23,732)	(27,600)	(3,500)	(38,139)	(20,800)	—	(16,309)	(2,000)	(63,726)	—
	1,647,689	618,444	421,000	167,496	142,966	80,732	65,524	44,500	26,378	203,838	(916,735)
					1922						
										Russia	
U. S.	112,000	—								—	112,000
Chile	90,000	41,000								—	47,000
Canada	82,000	35,000								—	47,000
Belg. Con.	14,000	—								—	14,000
Europe	12,000	—								12,000	—
Australia	9,000	1,000								—	8,000
Africa	9,000	—								—	9,000
Japan	3,000	—								—	3,000
	331,000	78,000								12,000	239,000

U. S. Production 1952 — 923,192.

* Includes unrefined black, blister, and converter copper, and refined metal but not scrap.

† Importer totals may also include tonnages from minor exporters not large enough to appear individually. Totals of vertical columns, therefore, may also be larger than the sum of their listed parts.



Other large exporters to the U. S. are Canada and Mexico, and access to these countries is even more easily maintained. Exports to the U. S. from Europe, Germany, and Yugoslavia, amounted to about 24,000 tons in 1952, an amount which could easily be acquired from sources in this hemisphere. Northern Rhodesia sent some 28,000 tons to the U. S. in 1952, and though access to it is not vital, this source of supply well might be kept open if war were to break out on a major scale.

The pattern of imports to the United Kingdom was quite different than that to the U. S. Northern Rhodesia was that nation's largest supplier, but the U. S., Canada, and Belgium-Luxemburg furnished from 50,000 to 30,000 tons each. An additional 17,500 tons comes to the United Kingdom from Germany which is not balanced by the 3,000 tons sent in the opposite direction.

As would be expected, the major share of copper imports to Belgium-Luxemburg came from the Belgian Congo (nearly 120,000 tons) with about 20,000 tons each coming from Northern Rhodesia and Peru. France obtained copper from three sources in about the same amount, the Belgian Congo, Belgium-Luxemburg, and the U. S. Germany depended in largest part on Chile and the U. S., with appreciable amounts also derived from Northern Rhodesia and Belgium-Luxemburg and minor amounts from Norway, the United Kingdom, and Yugoslavia.

Italy and Sweden were fairly large importers of copper in 1952, with the U. S., Chile, the Belgian Congo, and the Union of South Africa having been the main suppliers for Italy. Northern Rhodesia, Belgium-Luxemburg, and Germany provided most of the Swedish copper. For a mineral-rich country, Australia was a surprisingly large importer of copper (over 26,000 tons in 1952), of which nearly 20,000 came from Africa.

Of the principal exporters, Chile exported mainly to the U. S., Northern Rhodesia to the United Kingdom, the Belgian Congo to Belgium-Luxemburg, Belgium-Luxemburg to a large number of countries (of which the two most important were France and the United Kingdom), and Canada principally to the U. S. and the United Kingdom.

The picture here presented is one of industrially undeveloped countries exporting to the country to which political and/or economic ties bind them. Those importing countries which lack large resources at home and have to depend on relatively recently formed economic ties only, obtain their copper from a greater variety of sources in more evenly distributed amounts, e.g., France, Germany, Italy, and Sweden. On the other hand, the United Kingdom depends mainly on its south-central African dominion of which Northern Rhodesia is one of the component parts; and the U. S. on Chile, with which the economic ties are of long duration but with whom the political relationship is far less satisfactory than that of the U. K. with Northern Rhodesia; and Belgium-Luxemburg on the Belgium Congo.

The International Mineral Trade Series—

In this issue MINING ENGINEERING presents the fifth of a continuing series of articles on movement between nations of the vital minerals, the essential metal raw materials. Part I and Part II appeared in the May issue, Part III and Part IV in the June issue.

Additional articles in the series to appear in forthcoming issues include ones covering lead, zinc, tin, mercury, bauxite, and aluminum.

REPRINTS: No requests for reprints will be filled until the completion of the series. At that time an announcement will be made in MINING ENGINEERING as to availability of the complete series of articles.

Ultra-Portable Exploration Drills

THE old single-jack may have been portable—but it left much to be desired in drilling speed and depth of hole. Portable compressors for drilling can be snaked into tough spots. However, that calls for more men, equipment, and money, with corresponding loss of mobility. The drills listed in this notebook sheet meet three requirements: They are light. They are self-powered. And all are reported proven in practice. Undoubtedly there are other units filling the requirements that are not listed.

Extreme mobility for far-flung exploration teams is always an acute need. The drills listed here help solve the problem. Canadian Longyear, for instance, reports that the Porta drill has been parachuted into wilderness spots and helicopters have lofted light core drills onto mesa tops in the Colorado Plateau uranium country.

The gasoline-powered rock drills find use in construction as well as exploration, especially those that work at angles up to 45° above the horizontal. Secondary breakage and demolition are among jobs they can do well, and each of the three shown has a paving breaker model available or the rock drill itself can be modified. Power sources vary. Two of the gasoline-powered rock drills have integral engines. Still another drill uses electric power from line or becomes self-powered with separate engine-generator set.

The lightest core drills use two engines, one being mounted reminiscent of an outboard motor and the second on the detached pump. Performance report from Alaska for one of the drills used in exploring a magnetite deposit gave these results: Total drilled in six days was 263 ft, average hole 43 ft, core recovery 97 pct, bit life 40 ft, and bit cost 50¢ per ft. Total direct cost of about $1 per ft included 4 gal of gas per day, one driller's time, and a reaming shell at $21.40, but excluded transportation, maintenance, and depreciation. Cost would rise for holes approaching 100 to 120-ft maximum for the drill.

Warsop Gasoline-Powered Rock Drill

One operator testing a shallow industrial mineral deposit (100 to 200-ft holes) changed to a light core drill from more conventional equipment on skids. He found greatest advantages were reduction of drill crew from three to two, freedom in site selection, and elimination of need for tractor and operator to stand by for frequent short moves.

Use of a gasoline-powered rock drill for bulk sampling at a Canadian iron ore property eliminated need to rough out roads with a dozer. At test pit sites two successive holes were shot hard to clear pit without shoveling. The third hole was shot light to provide the sample. Result was that ample fresh material for beneficiation testing was obtained 4 to 8 ft below weathered and glaciated surface—at minimum investment.

Two Gasoline-Powered Rock Drills

Warsop Rock Drill: (Illustrated above.) Powered by a built-in 2-cycle gasoline engine, this drill has fully automatic rotation, air filtration system for engine, and air blast cuttings removal. Capacity is reported 8 to 10 ft in hardest rock. **Manufacturer:** Warsop Power Tools Ltd., 42 Northline Road, Toronto.

Pionjar Gasoline Drill: Integral single-cylinder, two-stroke engine has floatless carburetor permitting drilling to 45° above horizontal. Drilling depth is 13 ft and continuous blower cleans hole. Drill converts to paving breaker. Manufactured in Sweden. **Distributor:** Stanco Mfg. & Sales Inc., 1931 Pontius St., Los Angeles 25.

Two Light Diamond Drills

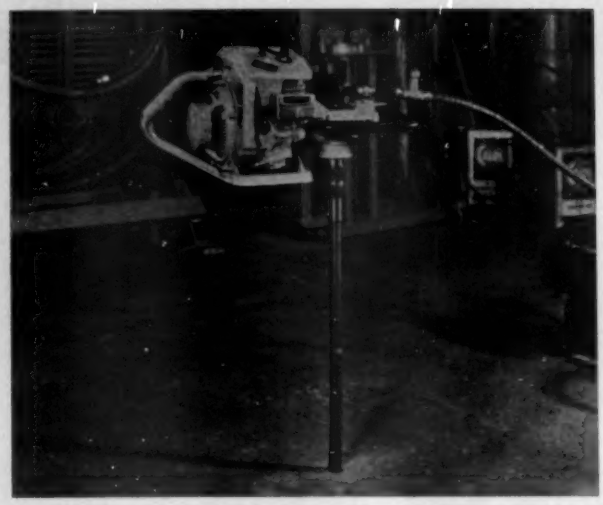
X-Ray Diamond Drill: Options include two gasoline engines, 3¾ or 7 hp, and 2½-hp air motor for underground use. Power supply and water pump are integral and companion pump is available for extra capacity. Is termed lightest and most efficient prospectors core drill. **Manufacturer:** Boyles Bros. Drilling Co. Ltd., Kirkland Lake, Ont. Distributed by Stanco Mfg. & Sales Inc., Los Angeles.

Porta Core Drill: Direct drive is feature of this drill powered with air-cooled gas engine. Capable of drilling to 200 ft, will also take E size for 1½-in. hole with 100-ft capacity. Enclosed head, gears running in oil, and safety chuck are among features. **Manufacturer:** Canadian Longyear Ltd., North Bay, Ont. Distributed by E. J. Longyear Co., Minneapolis.

Two Ultra-Light Core Drills

Super Pioneer Core Drill: Builder terms this a thoroughly tested, fully guaranteed, one-man tool that drills more than 100 ft. (Illustration at right.) Drill weighs 35 lb, the pump 49 lb, and the rods 1.2 lb per ft. Penetration is stated comparable with standard rig drilling EX holes. **Manufacturer:** Diamond Drill Contracting Co., South 18 Stone St., Spokane. Distributors in Northwest and Alaska.

Packsack Diamond Drill: Total weight of this drill with motor and integral transmission is about 35 lb. With separate pump, rods, crating, etc., complete outfit weighs 200 lb. The drill and pump will both fit into medium size packsack for carrying by one person. Cutting speed is reported 2 to 8-in. per min with capacity to 50 ft. **Manufacturer:** Packsack Diamond Drills Ltd., North Bay, Ont.



Two Other Portable Drills

Pinazza Rock Drill: (Illustrated at right.) Power for this drill comes from separate 3.5 to 5.5-hp gas engine which also drives a small rotary compressor; electric motor is also used. Air is only used for hole cleaning; drilling action is powered by flexible shaft. Drill may also be operated wet. Manufactured in Italy. **Distributor:** Pitman Industrial Products Co., 608 Fifth Ave., New York 20.

Demo Core Drill: Utilizing a rotary cutting action, the carbide-tipped bit strikes 8400 blows per min while rotating 350 rpm. Machine weighs only 50 lb. Using about 8 amp on 110-v ac-dc current tool becomes self-powered with Gen-A-Matic generator. Claimed drilling depth is 100 ft and hole drilled ranges from ½ to 6-in. diam. **Manufacturer:** Demo Tool Corp., 8735 Melrose Ave., Los Angeles.

Roundup of Portable Exploration Drills

Drill	Type	Power, hp	Depth, ft and Hole Size, in.	Weight, lb	Cost of Drill, $*	Manufacturer or Distributor
X-Ray	Diamond Core	2½ to 7 hp Gas or Air	200 1 3/16	155 to 190	1750 (complete)	Boyles Bros. Drilling Ltd.
Porta	Diamond Core	3½ Gas	200 or 100 1 3/16 or 1½	250 (mounted)	—	Canadian Longyear Ltd.
Super Pioneer	Diamond Core	5 Gas	100 1 3/16	Drill 35 Pump 49	735 (less rods)	Diamond Drill Contracting Co.
Packsack	Diamond Core	3½ Gas	50 1 3/16	Drill 35 Pump 65	850 (complete)	Packsack Diamond Drills Ltd.
Warsop	Rock Drill**	Gas piston	8 to 10 (⅞ hex steel)	90	650	Warsop Power Tools Ltd.
Pionjar	Rock Drill**	Gas piston	13 (⅞ hex steel)	86	—	Stanco Mfg. & Sales Inc.
Pinazza	Rock Drill**	3½ to 5½ Separate Gas or Electric†	6½ to 16½****	Drill 35 to 49 Power unit 90 to 115	—	Pitman Industrial Products Co.
Demo	Rotary Core	8 amp, 110-v Electric	100 ½	50***	—	Demo Tool Corp.

* Cost approximate, believed correct at time of publication
** Paving breaker available.
*** Weight of separate generator not given.
**** Uses standard U.S. drill steels
† Separate power unit with flexible shaft and hose connections.

Synthesis and Properties of Large Single Crystals of Strontium Titanate

by Leon Merker

FLAME fusion growth of strontium titanate crystals was undertaken to obtain large transparent crystals on which physical data could be gathered. The fact that strontium titanate is a cubic crystal and probably has a high index of refraction indicated that it might be useful in optics. No large boules* of strontium titanate had been synthesized previously, and none have been found as natural occurrences.

* *Boule*, the French word for *globule*, is generally accepted to describe any crystal grown by the flame fusion technique. It was introduced in this sense by A. V. Verneuil.

The flame fusion process, invented by Verneuil in 1904,[1] was first applied to grow large crystals of ruby and has since been used extensively to grow crystals of corundum and spinel on a commercial scale. Only during the past nine years has this technique been applied to the growth of large single crystals of other high melting compounds such as rutile,[2] mullite,[3] and ferrites.[4]

One of several significant advantages of the flame fusion technique over more conventional methods of growing crystals from a melt is that the crystals are grown without the use of melt containers. This fact alone excludes other methods of growing crystals from a melt whenever there are compounds with a melting point near 2000°C or above. Growth of the crystal, similar to that of a stalagmite, takes place inside a circular refractory furnace that does not contact the crystal, Fig. 1. This eliminates a serious source of impurities as well as the likelihood of multi-crystalline solidification along the container walls.

The flame fusion technique is particularly advantageous for research because it produces large crystals quickly and at lower cost. A corundum crystal 25 mm long and 12 mm in diam can be grown in 2 to 3 hr. Operating conditions permit observation of the growing crystal during any stage of the process. The various flame patterns and a wide range of oxidation-reduction conditions can be investigated in a relatively short time.

It should be pointed out that formation of the *foot* of the boule is the most critical step in growing an unfractured boule. When the tip of the sintered cone is fused to initiate crystal growth, the original area of fusion should be kept as small as possible so that one crystallite can assume dominance over all the others and propagate as a single crystal. If the boule start happens to consist of several crystals, usually the entire boule also contains several crystals. In many cases these tightly cohering crystals exhibit different crystallographic orientations.

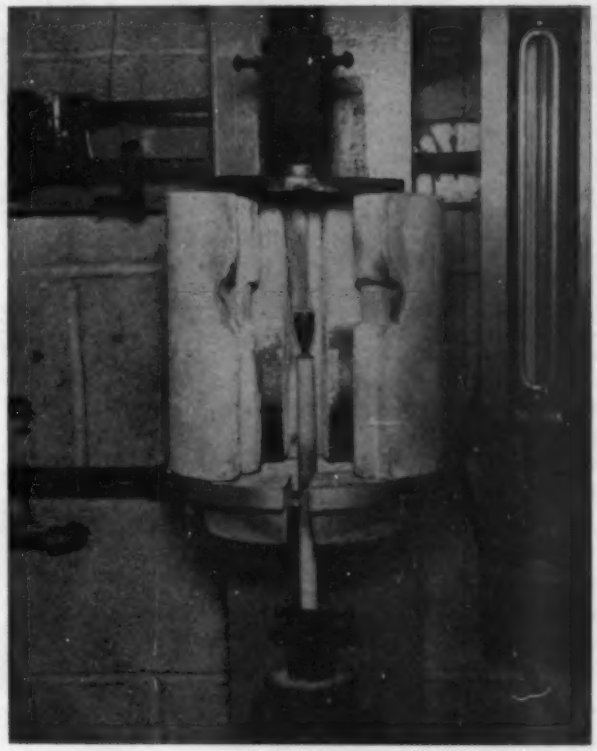


Fig. 1—Photograph of strontium titanate boule inside open boule furnace.

Although the basic technique of the original Verneuil process has been retained, refinements in method and burner design have been developed in recent years. For example, boule growth may be initiated on a seed crystal rather than by fusion of a sintered cone. The danger of multicrystalline or twinned boule starts is thus eliminated, and this procedure may also be used to grow boules of predetermined crystallographic orientation.

Prior Art: Of the many attempts to produce artificial gem crystals, most early efforts[5] were directed toward synthesis of rubies and sapphires and diamonds. None of these efforts resulted in a process that was commercially practical. Without exception only tiny crystals of corundum were obtained, and those at excessive cost. Verneuil announced his process in 1904; Ravier[6] in 1934 presented a detailed description of a commercial boule production plant. Descriptions of the German synthetic stone industry, the process details, and the equipment used have been published by Barnes[7] and by Merker.[8]

L. MERKER is a Research Chemist, Research Laboratory, Titanium Div., National Lead Co., South Amboy, N. J.

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The Transactions papers appearing in Mining Engineering during 1955 will subsequently appear in AIME Transactions Volume 202 and may be permanently referenced to that volume.

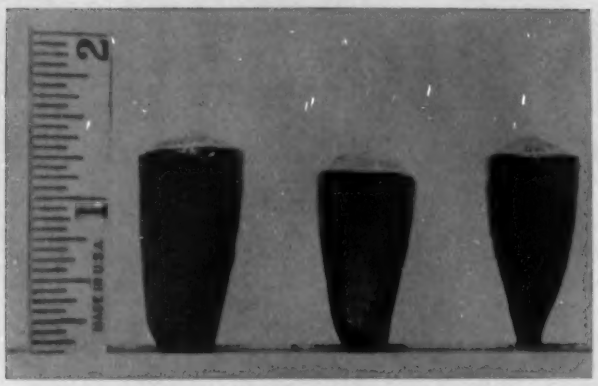

Fig. 2—Photograph of typical strontium titanate boules.

Until 1940 commercial application of the flame fusion technique was almost exclusively practiced in Europe, particularly in France, Switzerland, and Germany, and was limited to corundum and spinel. At the start of World War II the method was introduced to the U. S. for manufacture of corundum boules for instrument bearings. Important developments such as rod crystals,[9] synthetic star sapphires, and star rubies[10] were soon realized. In 1949 Moore[3] described the flame fusion synthesis of large single crystals of rutile and in 1950 Bauer and coworkers[5] reported synthesis of single crystals of mullite by flame fusion. Zerfoss and coworkers[11] described the synthesis of scheelite crystals, and more recently Bauer[4] also discussed the successful synthesis of large ferrite crystals by a similar technique.

Experimental Details

The first attempt to grow a single crystal of strontium titanate by flame fusion with a tricone burner[3] such as that used for growing rutile boules produced a small transparent crystal 7 mm long and 2 mm in diam. Although no effort was made to grow a larger crystal, the experiment clearly demonstrated the feasibility of obtaining transparent single crystals of strontium titanate by flame fusion.

Subsequent experiments with the tricone burner resulted in boules, invariably badly fractured, which contained solid pieces the size of a 6-mm cube. Some improvement was obtained when the sintered cone technique was replaced by the use of seed crystals, small unfractured strontium titanate crystals shaped into narrow rods 8 mm long and 3 mm wide. The seed crystals were cemented to the top of the refractory pedestals by a refractory cement mixture made into a barely moist paste by the addition of a few drops of a dilute sodium silicate solution. Before use, the seed crystal was fired over a blast burner until the cement appeared well hardened.

The larger boules grown with a tricone burner consisted of many sections of a variety of colors (white, yellow, purple, and dark blue) which separated on cooling. The opaque dark blue crystal sections, actually appearing black when the crystal section was more than 2 mm thick, were usually the largest and were mostly free of fractures. It was concluded that these colors represented different oxidation stages of strontium titanate and were the result of inhomogeneous oxidation-reduction conditions produced by the flame pattern of the burner. The opaque dark blue crystal sections exhibited the fewest fractures, and since it appeared simpler to provide a satisfactory flame pattern with reducing conditions, effort was directed toward growing boules that would consist entirely of the blue phase.

It became apparent that the tricone burner was not suitable for growing large unfractured boules of strontium titanate. Designed to grow rutile boules at a fusion temperature of 1830° to 1870°C, the burner did not provide a satisfactory flame pattern when the oxygen flows were increased to reach the temperature (2080° to 2130°C) required for fusion of strontium titanate. With this consideration in mind, a modified Verneuil type of burner was set up. Investigation of a wide range of gas flow combinations indicated that a satisfactory flame pattern can be obtained with gas flows in which the hydrogen-oxygen ratio is kept at approximately 5:1, by volume. By taking advantage of the uniformly reducing atmosphere obtained with this burner, it was possible to grow unfractured boules up to 20 mm long and 10 mm in diam, weighing up to 20 grams. Best results were obtained when the temperature of the molten boule surface was kept between 2100° and 2130°C, as determined with a Leeds and Northrup optical pyrometer.

Description of the Boule-Growing Process

The calcined strontium titanate feed material is screened through a 100-mesh nylon screen. The feed hopper as well as the burner system are cleaned thoroughly by blowing out with filtered air to remove dirt and dust particles, and then the hopper is loaded with about 200 grams of feed material.

A refractory pedestal, with a seed crystal cemented to its top surface, is placed inside the open boule furnace so that the seed crystal extends upwards to the lower edge of the furnace window. Gas flows are adjusted so that the burner may be lighted without either fracturing or melting the seed crystal. For this purpose the needle valves are set so that the hydrogen-oxygen ratio is approximately 10:1.

To light the burner a taper or pilot light is held in the open boule furnace just below the burner orifices, and the simultaneous shutoff valve is switched open. After the furnace is closed the hydrogen flow is increased to its maximum and is kept unchanged throughout the run; only the oxygen flow is used to control the flame temperature. The seed crystal is then slowly raised until it extends to the middle of the furnace window, and the oxygen flow is gradually increased. When the seed crystal appears well heated without signs of fracturing, the flow of oxygen is further increased until the top of the seed crystal appears uniformly molten. This point should

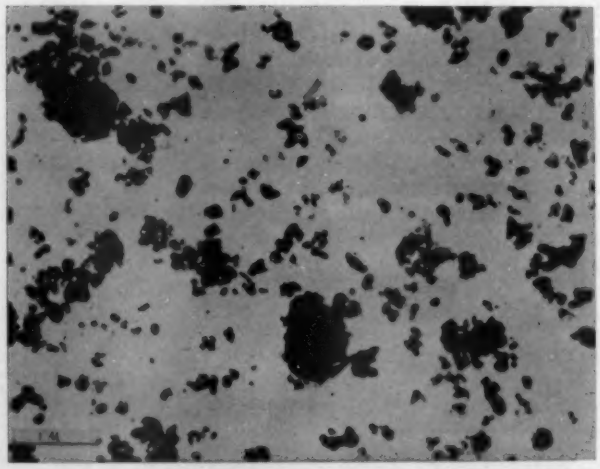

Fig. 3—Electron micrograph of boule feed.

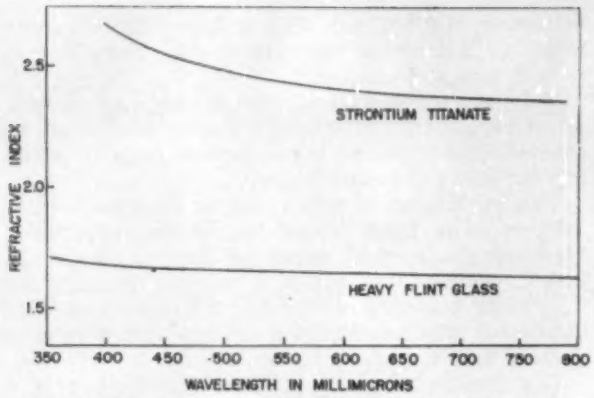

Fig. 4—Refractive index of strontium titanate and a heavy flint glass as a function of wave length.

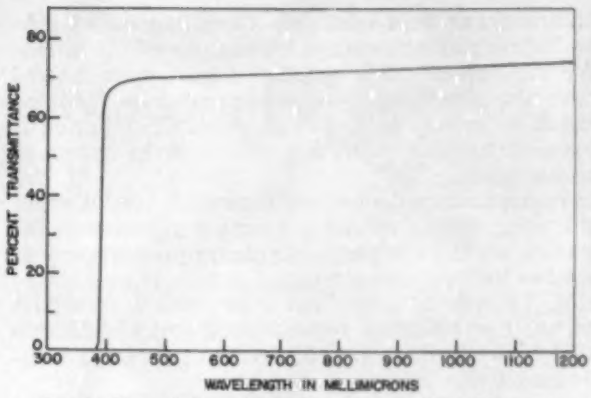

Fig. 5—Transmission of strontium titanate from 300 mμ to 1200 mμ.

be reached when the hydrogen-oxygen ratio is about 9:1.

The feed mechanism, adjusted to a rate of 30 taps per min, is then put into operation. To center the seed crystal with respect to the feed stream, the pedestal holder is carefully moved until it appears that the feed stream is striking the center of the molten surface. After the seed crystal has grown by 3 to 6 mm, the oxygen flow is increased by small increments until the ratio of hydrogen to oxygen reaches 5:1, which causes the rod-like crystal to assume a mushroom shape. This widening process is continued until the boule is about 12 mm wide. No attempt should be made to widen the crystal further, as it might then exceed the width of the hot zone of the flame. This causes the boule to fracture on cooling.

After the boule has reached the desired width the oxygen flow is not increased. The feeding intensity is now increased, and by keeping all gas flows constant the boule is allowed to grow straight without further widening. Temperature of the molten boule surface, measured with a Leeds and Northrup optical pyrometer, should be kept at 2100° to 2130°C throughout the run. To compensate for its upward growth the boule is lowered every 5 min by approximately 2 mm. The boule surface is thus kept at approximately the same temperature zone of the flame. When the crystal has reached a size of approximately 20 grams, equivalent to a height of 30 to 35 mm, feeding is discontinued. The boule is then lowered by 5 to 7 mm to avoid fracturing when the flame is shut off by a valve which simultaneously stops the flow of both hydrogen and oxygen. The boule is allowed to cool inside the furnace for ½ hr. The furnace is then opened carefully so the pedestal will not be jarred, and the hot boule is removed by asbestos-covered tongs. For protection from air drafts the boule is placed in an asbestos-clad box until it has reached room temperature. The burner tips are then cleaned to remove any adhering feed particles, the pedestal is replaced, and the burner is ready for another run.

Production of a boule of good quality depends on careful and regular maintenance of burner and gas control equipment, skill of the burner operator, and such factors as feed material and burner design. Proper centering of the seed crystal is very important, as otherwise excessively strained crystals are produced which usually fracture during cooling. If the top of the seed crystal is not completely fused prior to the start of feeding, the boule also tends to fracture. Runovers will occur if the oxygen flow is increased too rapidly. Whenever a runover occurs the growth process should be discontinued, as the resulting crystal usually comes out badly fractured. If the boule is allowed to grow too high into the cooler portion of the flame, the upper center portion of the crystal will contain a region of unfused feed particles.** Fig. 2 is a photograph of typical boules.

** A description of the boule-growing process is also contained in a patent issued to Lynd and Merker.[12]

Feed Material: As part of the problem of the growth of strontium titanate crystals, it was necessary to prepare a strontium titanate feed material of very high purity and satisfactory chemical and physical properties. This procedure relies on the precipitation of a strontium titanium oxalate, which on calcination at 1000°C forms strontium titanate of stoichiometric composition with good free-flowing properties. The precipitation of the double salt requires great care: a solution of oxalic acid is added to dilute titanium tetrachloride, followed by the addition of a solution of strontium chloride. The solution is kept at 70°C under agitation. Precipitation begins 15 to 20 min after the solutions are mixed, and with continued agitation the precipitate is allowed to age for 10 to 11 hr. It is then filtered, washed free of chlorides, and calcined in an electric muffle furnace at 1000°C for 2 hr. The resultant strontium titanate is of high chemical purity, as may be seen in Table I, which represents a typical spectrographic analysis of boule feed material. Chemical analysis shows 43.4 to 43.6 pct TiO_2, 43.5 pct TiO_2 being the theoretical value.

Table I. Spectrographic Analysis of Boule Feed

Element	Pct	Element	Pct
Si	0.02	Pb	0.0005
Fe	<0.001	Mn	<0.0001
Al	<0.001	W	<0.01
Sb	<0.002	V	<0.002
Sn	<0.001	Cr	<0.002
Mg	0.001	Na	<0.1
Nb	<0.02	Ba	<0.001
Cu	0.0002	Ca	<0.005
		K	<0.1

Frequent variations in flow characteristics and particle size of individual batches, however, suggested the need for a more complete investigation of precipitation conditions. A series of experiments was carried out to determine how large an excess of both oxalic acid and strontium chloride is required to obtain complete precipitation. Assuming for the double salt the formula $TiO(C_2O_4)_2Sr \cdot 2H_2O$, the amounts of oxalic acid and strontium chloride were varied while the amount of titanium tetra-

chloride was kept constant. Completeness of precipitation was determined by analysis of the filtrate for Ti^{4+} values. This series of experiments showed that the most complete precipitation is obtained when an excess of 25 pct of strontium chloride is present, together with a similarly large excess of oxalic acid.

Previous experience had shown that dilution of the precipitating solutions exerts a pronounced influence on the completeness of the precipitation as well as the flow characteristics of the calcined material. The effects of dilution were studied, therefore, in another series of experiments, which indicated that high dilutions are required to produce a free-flowing boule feed.

A study of calcining conditions showed that feed material of optimum feeding characteristics is obtained by calcining the strontium titanium oxalate for 2 hr at 1000°C. The calcination is carried out in flat-bottom silica trays, in either Globar or wire-wound muffle furnaces. Fig. 3 represents an electron micrograph of a typical boule feed material; it shows that the ultimate particle size of the feed material is between 0.2 and 0.5 microns. The feed material actually consists of aggregates 5 to 10 microns in size. Prior to use in the boule burner, the calcined strontium titanate is screened through a 100-mesh nylon screen.

Table II. Physical Properties of Strontium Titanate Crystal

Crystal system	Cubic
Unit cell size (a_0)	3.90 A°
Space group	O^1_h
Index of refraction	
n_C	2.380
n_D	2.409
n_F	2.488
Dispersion (n_F-n_C)	0.108
Reciprocal relative dispersion	13
Critical angle	24° 32′
Transmission range	0.395 to >1.7μ
Specific gravity	
measured	5.122
theoretical	5.124
Hardness	
Mohs scale	6 to 6.5
Knoop microindentor	595
Melting point	2080°C
Dielectric constant (100 kc)	310
Loss tangent (100 kc)	0.0003
Fracture	Conchoidal
Optical anisotropy	No evidence

Oxidation of Boules: As previously mentioned, when a boule is removed from the boule furnace it has an opaque black appearance. This color actually is a very dark blue, which may readily be observed in thin sections of the crystal. Analogous to that of rutile boules,[8] this color indicates an oxygen-deficient crystal of strontium titanate in which some oxygen ions are replaced by electron pairs. To obtain a colorless transparent crystal, it is necessary to restore to the crystal the missing oxygen ions. This is achieved by heat treating the crystal in air or oxygen at elevated temperatures until the fully oxidized boule appears essentially water-white. The heat treatment may at the same time be utilized to produce a more strain-free crystal.

Physical Properties of Strontium Titanate Crystals

Hardness: Strontium titanate crystals are slightly softer than rutile. With a Knoop indenter, a hardness value of 595 is obtained, corresponding to 6 to 6.5 on the Mohs scale.

Optical Properties: Belonging to the cubic crystal system, the crystals are optically isotropic. When fully oxidized they are transparent and colorless, possessing a very high dispersion and an index of refraction of 2.409 (n_D). Fig. 4 shows the refractive index as a function of wave length, compared to that of typical flint glass.[14]

The color of strontium titanate crystals is very sensitive to impurities, and extreme care must be observed throughout all production steps if colorless crystals are to be obtained.

Two basic types of colors may be observed. Colors ranging from light yellow to red and eventually black are produced by impurities such as Fe, Co, Cr, and V, whereas blue colors of varying intensity are due to the presence of trivalent titanium ions. The blue color may be stabilized by ions with a valence greater than 4, such as W, Nb, and Ta.

The transmittance of strontium titanate over a wide range of the spectrum is shown in Fig. 5. The loss of transmission for wave lengths between 400 and 1200 mm is almost entirely reflection loss due to the very high index of refraction of the material.

A more complete account of the optical data is contained in a paper now being prepared by Levin, Field, and Merker.[15]

Density: The density is 5.122, which is considerably higher than for rutile (4.26) or diamond (3.25).

Electrical Properties: The value for the dielectric constant (100 Kc) is 310, with a loss tangent of 0.0003. More complete data on the electrical properties of strontium titanate crystals have been published by Linz.[13] The physical properties of strontium titanate crystals are given in Table II.

Summary

A process has been developed by which transparent colorless crystals of strontium titanate can be produced under carefully standardized conditions. Some unusual physical properties of these crystals indicate that they may have special use in optics, as well as applications in other fields. When properly cut and polished gem stones of great beauty are obtained, resembling diamond gems more closely than any other material known. The present equipment, described in this report, can produce boules up to 35 mm long and 15 mm in diam.

Acknowledgments

The possibility of growing large single crystals of strontium titanate was conceived in cooperation with L. E. Lynd of the Research Dept., Titanium Div., National Lead Co., who assisted in developing the process for preparation of feed material. A. Linz and K. Herrington made some of the physical property determinations. The author acknowledges also the cooperation of other members of the Research Dept.

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Coal Preparation with the Modern Feldspar Jig

The only fine coal washer with proved automatic controls, the feldspar jig is capable of good efficiencies even at low separating gravities, handles a variety of products, and treats 150 tph and over.

by G. A. Vissac

IN continental Europe the feldspar jig is used almost exclusively for cleaning the fine sizes of coal; it operates with an artificial bed, made up generally of pieces of feldspar or of any other hard and heavy rock with good cleavages.

A primitive form of this machine requiring close supervision was used in this country years ago, but output was small. The modern machines are generally air-pulsated Baum-type jigs, with capacities up to 150 tph, and treat sizes from ⅜ in. to 0, usually previously dedusted or deslimed. These jigs are equipped with very accurate and sensitive automatic controls insuring satisfactory operation even at low separating gravity and with feeds irregular in quality and quantity. This paper will deal more particularly with coal cleaning separation, but the technical studies apply equally to all minerals.

Theory of the Feldspar Jig

To understand fully the operation of the feldspar jig and to appreciate its potential value, it is necessary to measure and analyze the motion of small particles of various specific gravities, falling in various media, under various conditions. As no practical formulas were available for that purpose, the writer has developed new theories and established new sets of formulas, which cannot be demonstrated here. They are applicable to all minerals and to many problems of coal or mineral concentration. These formulas do not pretend to absolute accuracy, but results, tested by comparison with experimentally recorded data, are sufficient for practical purposes, as they give definite indications of trends, relative values, and order of magnitude of the many factors involved.

For pulsating motions no earlier formulas are available. In the case of continuous currents or motions, such formulas as Rittinger's, Allen's, or Stokes', over a hundred years old, apply only to special shapes and sizes of particles, involve factors and coefficients difficult to measure or appreciate, and deal only with free motions. They are of little use in solving practical problems.

G. A. VISSAC, Member AIME, is a Consulting Engineer, Vancouver, B. C.

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Units used with the formulas presented here are in the CGS system. Lateral friction and suction have been taken into account according to methods currently used in aerodynamics, and only hindered motion is dealt with. As the feldspar jig is primarily intended to create a fluid bed condition, the mixture of fluids and solids obtained is homogeneous, and the apparent specific gravity of the separating medium is calculated accordingly.

For instance, if 20 pct of the volume is coal and shale, with an average of 1.60 sp gr, in a liquid of 1.10 sp gr, the actual specific gravity of the separating fluid is $0.80 \times 1.1 + 0.20 \times 1.6 = 1.20$.

The fundamental equations are as follows:

The general motion of a particle falling in a medium of specific gravity equal to u, hindered motion, is

$$\frac{dv}{dt} = \frac{g}{Ls}\left[L\,(s-u) - \frac{u}{g}\,v^2 \right] \qquad [1]$$

$g = 981$ cm per sec, acceleration of gravity, and $L =$ thickness of the particle of specific gravity (s) and velocity (v).

The initial acceleration

$$\frac{dv}{dt} = g\,(1 - \frac{u}{s}) \qquad [2]$$

is a function of the specific gravity of the particle, only for a given medium, and independent of its dimensions—an ideal separating condition.

The terminal velocity

$$V_t = \sqrt{g \times L \frac{(s-u)}{u}}, \qquad [3]$$

for a given value of u, is a function of s and L.

Two particles, L_1 s_1 and L_2 s_2, are said to be equivalent if they have the same terminal velocity, and accordingly

$$\frac{L_1}{L_2} = \frac{s_2 - u}{s_1 - u}. \qquad [4]$$

Two such particles cannot be separated by continuous currents, in any concentrating device.

Because the initial accelerated motion, which provides for efficient separation, is followed by a constant velocity, which has a limiting effect, it is essen-

tial to determine approximate size and duration of the initial accelerated motion. The following formulas are submitted:

$$\text{Distance of fall is } H = L \times \frac{s}{u} \qquad [5]$$

and

$$\text{duration is } T = 2\sqrt{\frac{L}{g} \times \frac{s^2}{u(s-u)}}. \qquad [6]$$

These formulas clearly indicate the short values corresponding to small size particles.

The strictly accurate formulas are

$$H = -\frac{Ls}{2u} \log_e \left[1 - \frac{v^2}{V_t^2}\right] \qquad [7]$$

and

$$T = -\frac{V_t}{2A_o} \log_e \left[\frac{1 - \frac{v}{V_t}}{1 + \frac{v}{V_t}}\right] \qquad [8]$$

with

$$A_o = \frac{dv_o}{dt_o}.$$

The equation of motion for upward currents or upsurge is

$$\frac{dv}{dt} = -\frac{uv}{sL}(2V_t + v) \qquad [9]$$

showing the destructive effect of this phase in the separation of equivalent particles.

The equation of motion for descending currents or downstrokes is

$$\frac{dv}{dt} = n\,(2\text{-}n)\,g\frac{s-u}{s} \qquad [10]$$

with $o < n < 2$, and velocity of the water $= nV_t$. This equation indicates that with a proper downsurge, or suction, ideal separating conditions can be achieved, with acceleration, only as a function of particle specific gravity, and independent of particle size. This is the real key to the success of the feldspar jig.

Operation

The jig usually consists of two or three boxes in series, Fig. 1; each box may be divided in two or three cells. A typical box is divided by a vertical partition. On one side is the air or piston compartment and on the other the washing compartment. The coal is fed at one end of the washing compartment, the clean coal is washed over an adjustable weir by the overflowing water, and refuse drops into the hutch below the screen plate supporting the bed. A layer of bedding material, generally feldspar, is placed on top of the screen plate, supporting the bed to be stratified. The feldspar bed opens during the upstroke and closes toward the end of the downstroke, thus acting as a foot valve, and preventing a drop of the whole bed en masse. Pulsations of the water in the washing compartment are obtained by the motion of a piston, or by admission and exhaust of compressed air in the adjacent compartment.

The average unit box is 6 ft long and 5 ft 6 in. to 8 ft 6 in. wide for 60 to 100 tph capacity. The screen plate usually has ⅝-in. round perforations. The pieces of feldspar are 1x2 in. or 2x2 in. with an average thickness of ½ in. Average thickness of a feldspar bed is about 4 in.

Number of Strokes per Minute: A jig pulsation is a typical case of vibrating motion. According to the Fourier theorem: "Any type of vibrating motion, no matter how complicated, in which the same motion is repeated over and over again, may be regarded as the sum of a fundamental simple harmonic vibration, plus other simple harmonic vibrations, whose frequencies are whole number multiples of the frequency of the fundamental (or harmonics)."

In this case, the fundamental vibration can be compared to the motion of a compound pendulum representing the masses in motion, and the period of the pulsation will be given by the basic formula

$$T = 2t = 2\pi\sqrt{\frac{L}{g}}. \qquad [11]$$

T and t are expressed in seconds; $\pi = 3.14$; and $g = 981$ cm. L, expressed in centimeters, is the distance between the center of suspension of the compound pendulum G and its center of oscillation O as represented in Fig. 1.

Assuming 50 complete pulsations per min, $T = \frac{60}{50} = 1.2$ sec, and $t = 0.6$, the duration of each stroke (upstroke plus downstroke).

An entirely wrong conception has long prevailed in this connection. By use of small laboratory jig models, it had been found that the most suitable number of pulsations for small particles (about 1 mm) should vary between 120 and 240 per min. However, as larger jigs were built, it was realized that the rate of pulsations had to be reduced in proportion. Large jigs, such as the Mogul, treating over 300 tph, operate at 30 pulsations per min. Smaller jigs, treating 75 tph, run at 60 pulsations per min.

Obviously, considering the tremendous mass in oscillating motion (as much as 20 tons) the water must be allowed to follow its natural pulsation, and the equation giving the value of this natural pulsation, namely,

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad [12]$$

indicates that it must vary as the square root of the length of the corresponding compound pendulum, that is,

if $T = 1$ sec (60 pulsations per min)
for $L = 0.25$ m,
$T = 2$ sec (30 pulsations per min)
for $L = 4 \times 0.25 = 1$ m.

To ignore the above principles will result in dangerous pounding of the jig, waste of power, and disturbing eddies, particularly dangerous with small size particles.

Length of Stroke: The length of the stroke or amplitude of the pulsation, A, is generally considered as a function of the period of the pulsation and expressed by the following formula, attributed to Rittinger:

$$V = nA\frac{\pi}{60}. \qquad [13]$$

V = velocity of the water, in. per sec, required to hold the bed in suspension; A = amplitude of the stroke, in.; n = number of strokes per min.

For example, a jig treating ¼ to 0 in. coal must dispose of a water velocity capable of raising the largest pieces ¼ in., or $V = 6$ in.

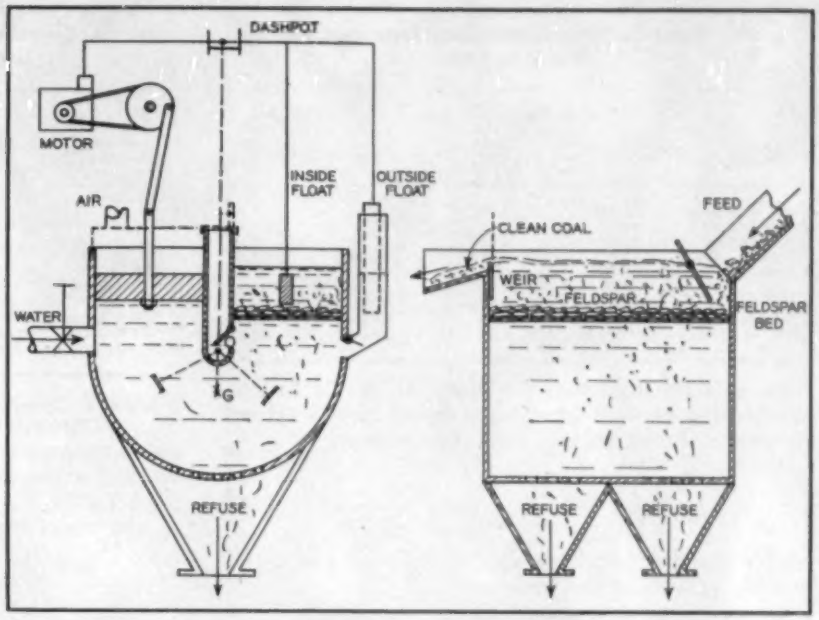


Fig. 1—Schematic view of the feldspar jig bed.

If it is assumed that $n = 60$ pulsations per min, then

$$A = \frac{6 \times 60}{3.14 \times 60} = 2 \text{ in.}$$

and a surge of 2 in. will be required.

Modulated Surges: The desirable shape of surge, that is, with the correct speed and proper timing, can be estimated by a proper application of the methods of calculation developed in the first section of this article. The three basic conditions already discussed will be found during a complete pulsation: 1) The upstroke corresponds to a condition of fall in an ascending current. 2) At the top of the upstroke there is a leveling off of the water surge, corresponding to the condition of fall in a still medium. 3) The downstroke corresponds to a condition of fall in a descending current.

Assuming a pulsating period $T = 1.2$ sec (or 50 pulsations per min), consider how two equivalent particles can be efficiently separated:

For coal $L_1 = 2$ m/m, $s_1 = 1.5$, $u = 1$.

For rock $L_2 = 1$ m/m, $s_2 = 2$, $u = 1$.

At the start of the upstroke both particles rest on the bed. As the upstroke develops, the particles will start to move up as soon as the water velocity reaches the common value of the terminal velocity. As the velocity of the water increases the two particles will move at a higher speed, and their accelerations will be in direct ratio to their specific gravities; the rock will gain over the coal.

The ideal condition of accelerated motions in practically still water obtain at the top of the upstroke: each particle falls at its own acceleration, a function only of its specific gravity. The downstroke will follow, during which water velocities must be controlled below a certain figure, ending with a short period of sharp suction, followed by a corresponding rise. Table I gives the values of the corresponding displacements.

At the end of the downstroke a short suction is necessary to withdraw the fine refuse through the screen plate and down the hutch.

The upstroke is modulated by proper control of the down motion of the piston or of the admission of compressed air, the downstroke by proper regulation of the speed of return of the piston or of the exhaust of the compressed air. The terminal suction is obtained by a sharp motion of the piston at the end of its upstroke, or of the air valve at the end of the exhaust period.

In one single stroke the rock has taken an advance of 0.60 cm over the coal. However, as the particles reach lower layers, to the clean water condition, ($u = 1$) will succeed heavier media and there will be lower values for the individual falls and the relative differentiations.

The stratification will generally be completed in 30 to 40 sec. The clean coal will then be in a top zone of some 5 cm which will overflow at one end of the wash box. The refuse will gradually sink to the feldspar bed, a distance of perhaps 50 cm.

Bedding Material: The artificial bed is ordinarily made of pieces of feldspar. Most feldspar rocks are of the plagioclase group, a range of varieties such as albite and orthoclase, chemically silicates of sodium or calcium and aluminum. They all have two good cleavages, at an oblique angle for the plagioclases, at a right angle for the orthoclases. The hardness is 6½, and the specific gravity varies from 2.538 (pure orthoclase) to 2.62 and up to 2.76 for the plagioclases. Dimensions and specific gravities of the rock used must be of suitable values to insure best efficiencies.

Assume a piece of rock of dimensions L, L, and $L/_n$ ($L/_n$ = thickness). An ideal motion for the par-

Table I. Modulated Surge for Separating Two Equivalent Particles

	Distances in Centimeters					
	Water		Rock		Coal	
Time in Seconds	Increment	$u = 1$ Cumulative	$L = 1$ mm Increment	$s = 2$ Cumulative	$L = 2$ mm Increment	$s = 1.5$ Cumulative
0.1	0.20	0.20				
0.2	0.50	0.70	0.27	0.27	0.27	0.27
0.3	1.00	1.70	0.79	1.06	0.69	0.96
0.4	2.30	4.00	1.90	2.96	1.80	2.76
0.5	1.00	5.00	0.79	3.75	0.69	3.45
0.6		5.00	0.60	3.15	0.40	3.05
0.7	0.35	4.65	0.95	2.20	0.75	2.30
0.8	0.70	3.95	1.30	0.90	1.10	1.20
0.9	1.05	2.90	1.65	0.75	1.45	0.25
1.0	1.40	1.50	1.70	2.45	1.80	2.05
1.1	1.75	0.25	2.35	4.80	2.15	4.20
1.2	0.25			4.80		4.20

Table II. Composite Data on Washability Tests at Mazingarbe, Sizes ½ to 8 mm

Specific Gravities	Raw Coal		Middling	
	Weight, Pct	Ash, Pct	Weight, Pct	Ash, Pct
Float at 1.30	32.54	1.83	4.10	1.85
1.30 to 1.40	54.41	3.38	17.24	4.25
1.40 to 1.50	58.98	4.48	27.69	9.44
1.50 to 1.65	63.97	6.48	47.05	17.80
1.65 to 1.80	67.14	8.19	60.58	23.40
1.80 to 2.00	71.45	11.10	72.50	28.60
2.00 to 2.20	75.83	14.36	80.13	32.20
2.20 to 2.40	81.47	18.74	86.41	35.50
Sink at 2.40	100.00	31.64	100.00	42.70

ticle will be such that the duration of its fall in accelerated motion is at least equal to the return motion of the equivalent pendulum, namely

$$2\sqrt{\frac{L}{g}\,\frac{s^2}{u(s-u)}} \geqq \pi\sqrt{\frac{L}{2g}} \qquad [14]$$

where s is the specific gravity of the rock and u the specific gravity of the medium.

However, as in this case, the pieces of rock oscillate on one edge and the weight and hence the volume involved are reduced by half, as is also the average orthogonal section. The above formulas therefore become

$$2\sqrt{\frac{L^3}{2n}\times\frac{2}{L^3}\times\frac{s^2}{u\times(s-u)}} \geqq \pi\sqrt{\frac{L}{2g}}$$

or with

$$\frac{\pi^2}{8} \sim \frac{5}{4}$$

$$4s^2 - 5nus + 5nu^2 \geqq 0$$

and $= 0$ for

$$s = \frac{5nu \pm \sqrt{25\,n^2u^2 - 80\,nu^2}}{8}.$$

As obviously $25\,n^2u^2 \geqq 80\,nu^2$, then $n \geqq 3.2$.

The thickness of the pieces of feldspar should be less than one-third their length, and this for all values of u. If, for example, $n = 3.3$ and $u = 1$, then $s_1 \sim 1.7$ and $s_2 \sim 2.5$.

Under the same conditions, but with $u = 1.2$, it will be found that $s_1 \sim 2.06$ and $s_2 \sim 2.94$.

Another factor controlling the desirable specific gravity of the bed material is the average specific gravity of the refuse.

When the bed is fully opened at the start of the downstroke, Eq. 15

$$A_0 = g \times \left[1 - \frac{u}{s}\right] \qquad [15]$$

shows that if particles of refuse are to drop ahead of the feldspar, their specific gravities should be higher or as near as possible to the specific gravity of the material used as bedrock. This second consideration will dictate the final choice between the two values given by the harmonic requirement.

Centre d'Etudes et Recherches des Charbonnages de France (Cerchar) has conducted considerable experimentation in this connection. Pieces of concrete and special clay products have been tried as filtering material. The published results are not always convincing. However, they agree with the present writer's conclusions, in that a rock of lower specific gravity than feldspar might, in certain cases, give better results.

Table III. Composite Data on Washability Tests at L'Escarpelle, Sizes 1 to 6 mm (1/25 to 1/4 in.)

Specific Gravities	Raw Coal		Middlings	
	Weight, Pct	Ash, Pct	Weight, Pct	Ash, Pct
Float at 1.30	70.33	2.17	19.38	2.85
1.30 to 1.40	79.38	3.26	32.66	7.04
1.40 to 1.50	83.14	4.19	47.60	11.42
1.50 to 1.60	85.31	4.93	59.81	16.05
1.60 to 1.70	87.03	5.68	70.70	20.30
1.70 to 1.80	88.59	6.51	78.75	23.40
1.80 to 1.90	90.00	7.31	85.49	26.10
1.90 to 2.00	92.59	8.97	92.87	29.25
2.00 to 2.20	95.85	11.36	97.41	31.60
Sink at 2.20	100.00	14.65	100.00	33.53

Table IV. Summary of Performance Data in Tables II and III
(Distribution of Errors in Feed, Weight Pct)

Mazingarbe			L'Escarpelle		
Separation, Sp Gr	First Separation	Second Separation	Separation, Sp Gr	First Separation	Second Separation
1.35	10.05	0.13	1.35	3.4	0.04
1.45	38.07	0.43	1.45	17.8	0.22
1.575	66.33	2.40	1.55	48.1	0.53
1.725	84.85	14.51	1.65	70.5	2.76
1.90	88.86	43.15	1.75	85.5	9.30
2.10	100.00	71.23	1.85	94.0	21.79
2.30	100.00	81.56	1.95	100.0	42.55
/2.30	100.00	87.91	2.10	100.0	65.63
			2.35	100.0	83.84
			/2.50	100.0	92.77
Specific gravity of separation	1.49	1.95		1.565	2.035
Efficiency, pct	92.3	97.7		94.8	99.4
Displaced material, pct	3.6	4.0		4.0	1.5
Probable error	+0.14 −0.085	+0.20 −0.16		+0.13 −0.08	+0.185 −0.175
Average	0.1125	0.18		0.105	0.18
Recovery:	Weight, Pct	Ash, Pct		Weight, Pct	Ash, Pct
Clean coal	57.00	5.6		78.50	4.09
Middlings	16.50	42.83		12.00	33.52
Subtotal	73.50	13.45		90.50	8.10
Refuse	26.50	80.70		9.50	78.08
Grand total	100.00	31.64		100.00	14.66

The above calculations do not pretend to any great accuracy; their only purpose is to demonstrate the existence of a definite relationship between the various factors involved.

Equipment

Piston Jig-Type Coppée: The present tendency is toward the use of the air-pulsated feldspar jig; however, over 60 pct of the existing equipment is of the piston type. A very popular type is made by the Belgian firm of Coppée. Total length is 108 in., total width 56 in., and width of the wash box 30 in. The washing area per box is 10 sq ft, the total washing area 20 sq ft. Capacity of the single-box type is 15 tph and capacity of the compound type 20 to 25 tph. On the average, 1000 gpm per box is used.

In this type the first compartment is sometimes fitted with a screen plate with small perforations, with a slope of about 7° towards the refuse discharge. The second compartment only is of the feldspar bed type with a horizontal screen plate. The first compartment in that case has a gate and dam refuse discharge. In the second compartment the refuse discharge is entirely through the filtering bed.

Both refuse discharges are often automatically controlled by a mechanical refuse discharge patented and manufactured by Preparation Industrielle des Combustibles (PIC). A compartment is connected at its base to the hutch of the jig. Any change in position of float is translated by a system of transmissions and compensations. If the bed becomes too

thin the float opens the air valve, releasing the pressure in the hutch.

The 100-tph air-pulsated jig manufactured by PIC, with three compartments in series, is 10 ft 6 in. long and 8 ft 6 in. wide. The 66-tph unit is 10 ft 6 in. long and 5 ft 6 in. to 6 ft wide. This jig is equipped with an air valve on the admission chamber, controlled by the float through an oil dashpot. An abnormal increase in bed thickness, due to an accumulation of refuse in the bed, results in closing of the air valve, so that less compressed air, if any, is allowed to leak; the air chamber receives the full pressure, and the pulsations their full amplitude. The procedure is reversed when the bed becomes too thin.

The air-pulsated jig manufactured by Schutermann & Kremer-Baum of Dortmund, Germany, is similar in construction, but valves and controls are different. SKB uses a sliding valve controlled by eccentrics. Each compartment is made up of three cells and each cell has an air valve. An increase in bed thickness due to an over-accumulation of refuse causes increased pressure in the jig air chamber, resulting in stronger water pulsation in the wash box.

New Types: Some new patented constructions developed in this country have been in use for over two years. These units, illustrated in Figs. 2, 3a, and 3b, will be described briefly.

Generally speaking, there is a primary box to make a heavy refuse, followed by one or two secondary boxes or compartments, producing a refuse, a clean coal, and one or two middlings. The first box collects the oversize refuse, if any, and the grease, dirt, and pieces of iron which may plug a feldspar bed. This is why some manufacturers, such as Coppée, use a sloping screen plate in the first compartment, but as they use no feldspar bed in this compartment they are compelled to use small perforations, which are liable to get plugged, introducing unnecessary resistance to the water.

The present writer has developed a semi-mobile feldspar bed for this primary box which offers certain advantages. Only part of the feldspar bed is retained on the screen plate; a certain amount is automatically removed with the coarser and heavier refuse, along with some of the foreign material, and extracted by the refuse elevator; at the discharge end of the refuse elevator there is a bar screen with sprays to wash the refuse, and the cleaned feldspar is returned to the jig. Changes in resistance of the

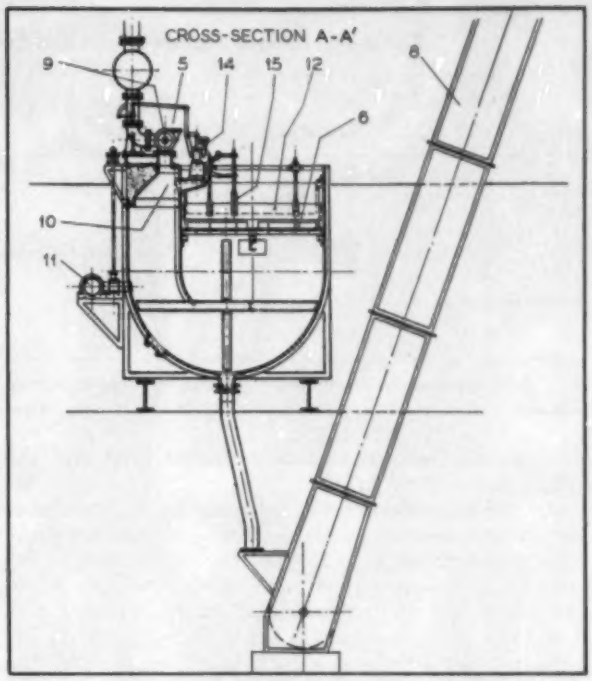


Fig. 2—The air-pulsated feldspar jig (Preparation Industrielle des Combustibles).

feldspar bed itself are registered in a float compartment connected with the hutch, as the float over the bed may be influenced by localized conditions. Inside the float compartment, depending on the type of control, either a float or a group of electrodes is used. The electrodes, through a relay, control various electric motors. As electrodes do not involve any mechanical friction, they are naturally more sensitive than any purely mechanical system. With fine coal, however, considerable foam is liable to collect over the surface of the water in the float compartment. The author has solved this difficulty by dipping the electrodes in a floating tank containing salt water.

In the mechanically pulsated jig both the motor driving the refuse extractor and the motor driving the pulsators can be controlled. In the air-pulsated type the air valves can be controlled.

Through modulated air or oil dashpots, a float in the bed or in the float compartment can control the

Table V. Operating Performances of Feldspar Jigs

Company and Location	Feed	Products	Weight, Pct	Ash	Separation, Sp. Gr.	Probable Error	Difficulty in ±0.10 Intervals	Efficiency Recovery, Pct
No. 6 mine,	100 tph,	Clean coal	73	7.3	1st, 1.50	0.06	7.6	
Sarre &	0.5 to 10 mm,	Middlings	12	37.3				
Moselle	20.58 pct ash	Refuse	15	71.8	2nd, 2.20	0.14	5.2	
(PIC)								
Chavanes,	63 tph,	Clean coal	85	11.2	1st, 1.84	0.06	9.1	
Blanzy	0.5 to 10 mm,	Middlings	3	58.6				
(PIC)	21.15 pct ash	Refuse	12	82.4	2nd, 2.10	0.10	7	
Chavanes,	63 tph,	Clean coal	79	9.0	1st, 1.59	0.06	9	
Blanzy	0.5 to 10 mm,	Middlings	3	40.0				
(PIC)	22.17 pct ash	Refuse	18	77.0	2nd, 1.73	0.08	7	
Cransac,	65 tph,	Clean coal	63.55	8.2	1st, 1.67	0.075	10	
Aveyron	0.5 to 6 mm,	Middlings	2.25	47.0				
(PIC)	32 pct ash	Refuse	34.25	75.0	2nd, 1.77	0.11	8	
Central Washery,	65 tph	Clean coal	60.0	5.1	1st, 1.38	0.04	7.6	
Lievin	0.5 to 10 mm,	Middlings	24.0	45.4				
(PIC)	27.8 pct ash	Refuse	16.0	84.6	2nd, 2.20	0.125	8	93
L'Escarpelle,	30 tph,	Clean coal	78.5	4.09	1st, 1.56	0.09	6	94.8
Douai	1 to 6 mm,	Middlings	12.0	33.52				
(Cerchar)	14.65 pct	Refuse	9.50	78.08	2nd, 2.03	0.17	5	99.4
Mazingarbe,	60 tph,	Clean coal	57.0	5.6	1st, 1.51	0.10	9	92.3
Bethune	0.5 to 8 mm,	Middlings	16.5	42.8				
(Cerchar)	31.64 pct	Refuse	26.5	80.7	2nd, 1.95	0.18	9	92.3

Table VI. Performance of a Group of Feldspar Jigs, Primary and Secondary Washing*

Feed	Products	Weight, Pct	Ash, Pct	Separation, Sp Gr	Probable Error	Efficiency, Pct
Two primary jigs:	Clean coal	30	5.2			
100 tph each	Middlings	45	26.8	1st, 1.37	0.06	90
0 to 10 mm	Refuse	25	76.0	2nd, 2.00	0.29	94.8
32.7 pct ash						
One rewash jig	Clean coal	46	8.8	1st, 1.44	0.08	91
90 tph	Middlings	44	33.4			
26.8 pct ash	Refuse	10	77.0	2nd, 2.00	0.15	98.1
Composite of final	Clean coal	50	6.75			
products	Middlings	19.8	33.40			
	Refuse	29.5	76.20			

* Data supplied by Faulquemont (Meurthe-et-Moselle) Centre d'Etudes et Recherches des Charbonages de France.

exhaust pressure in the air-pulsated type and the refuse gates in all types.

As the operation of the feldspar jig is dominated by the influence of suction, control of exhaust pressure seems more logical than the regulation of intake pressure employed with other designs. When too much fine dirt accumulates in the filtering bed, a sudden sharp suction is safer than a sudden increase in air pressure, which may carry some fine refuse over the weir with the clean coal.

Results

Methods of Control: Although it is still difficult to define true measures of cleaning efficiencies, there is general agreement on one point, namely, analysis of the distribution of particles of the same specific gravities, on a percentage basis, between the clean coal, middlings, if any, and refuse. On the basis of these frequency distributions, the corresponding probable errors may be determined. Cumulative results can be plotted on arithmetic coordinates, resulting in the S shape or Gauss distribution curve.[1] The ordinate of the 50 pct distribution is the actual gravity of separation; the ordinates at 25 pct and 75 pct give the probable errors.

As an alternative, the area of the Gauss curve between the 50 pct abscissae and the 0 and 100 pct ordinates gives the error curve. In many cases this method can be of great advantage, as it offers a more complete picture of the distribution over a wider range.

On a probability graph, theoretically, the distribution is represented by a straight line, easier to interpolate and capable of supplying very useful indications on the sampling accuracy and normality

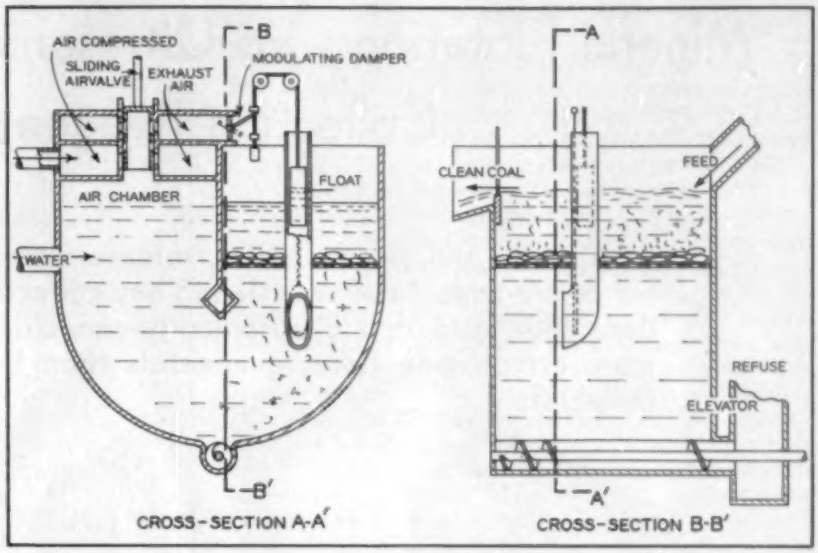
Table VII. Results of Performance of a Dense Medium Pilot Plant*

Test No.	Separation, Sp Gr	Error Area	Probable Error	Efficiency, Pct
Table 6,				
size 1 (2 in. to 1 in.)	1.526	6	0.029	99.6
2 (1 in. to ½ in.)	1.538	9	0.032	99.4
3 (½ in. to ¼ in.)	1.56	18	0.037	98.9
4 (¼ in. to 0)	1.58		0.04	98.6
Table 8,				
Test No. 30	1.69	19	0.04	99.9
37	1.59	38	0.052	99.9
35	1.68	102	0.096	99.0
31	1.30	13	0.03	93.9
54	1.34	18	0.035	89.4
32	1.35	14	0.036	97.3
25	1.40	13	0.032	97.1

Table VIII. Results of Performance*

Test and Feed	Size, mm	Separation, Sp Gr 1st	Separation, Sp Gr 2nd	Probable Error 1st	Probable Error 2nd	Efficiency, Pct 1st	Efficiency, Pct 2nd
A—Feldspar jigs, Freyming washery**	0.7 to 3	1.67	2.05	0.07	0.19		
1. 85 tph 0.7 to 10 mm raw coal	3 to 6	1.65	1.92	0.08	0.15		
25 tph crushed middling							
100 tph feed total	6 to 10	1.60	1.85	0.08	0.12		
Total	0.7 to 10	1.64	1.88	0.07	0.12	99.8	99.5
2. 85 tph raw coal	0.07 to 3	1.65	2.32	0.12	0.23		
10 tph middling							
95 tph total feed	3 to 6	1.52	2.13	0.06	0.16		
	6 to 10	1.50	2.03	0.05	0.12		
Total	0.7 to 10	1.55	2.15	0.07	0.16	99.6	99.6
						Clean Coal, Ash Pct	
B—Baum jig, Geddling, England	0.5 to 15	1.875		0.155		10.0	
160 tph total feed	15 to 25	1.70		0.11		5.6	
(all sizes 125x0 mm)							
	25 to 37	1.825		0.08		4.8	
	37 to 62	1.71		0.04		4.3	
	62 to 125	1.70		0.035		4.2	
C—Feldspar jigs, Freyming washery	0.7 to 3	1.625		0.05			
90 tph	3 to 6	1.55		0.07			
(test duration 2 hr, special bed)	6 to 10	1.475		0.06			
Total	0.7 to 10	1.55		0.06			

* From Cerchar Report 10/53, August 1953.
** Five compartments 8x5 ft; compartments 1 and 2, refuse; compartments 3 and 4, recirculated; compartment 5, final middling. Feldspar is used in compartment 1; Creramicher at 2.1 sp gr is used in compartments 2 through 5.



Figs. 3a and 3b—New types of automatic control for air-pulsated type of feldspar jigs (G. A. Vissac, patents applied for).

of the cleaning operation. However, one requirement too often overlooked is that the choice of class intervals must be constant and consistent, that is, within a proper range, as required by the Sturges formula[2]

$$i = \frac{R}{1 - 3.3 \log N} \qquad [16]$$

where i is the class interval and R the range of specific gravities considered. If $R = 2.00 - 1.25 = 0.75$, for example, then with $N = 100$, $i = \frac{0.75}{7.6} \sim 0.10$. For a range of 0.35 (gravities 1.45 to 1.80), $i = 0.05$.

Considerable information has been published by Cerchar in this connection. The interested reader is referred to its technical reports[5] dealing with methods of scientific control and their application to hundreds of careful tests made on various feldspar jigs. Generally speaking, the air-pulsated type indicates better results on a closely sized feed. The piston type show best results with feed of large size ratios, over 6:1.

Typical Tests: Tables II through IV illustrate two Cerchar tests on feldspar jigs at two French collieries, namely Mazingarbe and L'Escarpelle. The writer's own system of representation, however, will be used here. It will be noted that in most cases straight lines of representation have been obtained, an indication that experiments were made carefully and that jig operation was normal.

In both instances tests deal with the primary jig only; normally the middling product will be rewashed. If at L'Escarpelle, for example, the middling is rewashed at a 10 pct ash, theoretical recovery will be 42 pct, or at 90 pct efficiency there will be an actual recovery of 37.8 pct. Calculated on a feed basis, $37.8 \times 12 = 4.53$ pct clean at 10 pct ash and 7.47 pct refuse at 48 pct ash.

The final products will be 78.5 pct clean coal at 4.09 pct ash, plus 4.53 clean coal at 10 pct ash, equaling 83.04 pct clean coal at 4.425 pct ash, with 16.96 pct refuse at 64.70 pct ash. As the theoretical return is 83.35 pct at 4.425 pct ash, the overall efficiency is 99.4 pct.

Other Results: A wider range of tests is given in condensed form in Tables V and VI, dealing with feldspar jigs in various French fields. As a basis of comparison, operating results for a dense medium plant, extracted in condensed form from a paper by Geer, Olds, and Yancey,[3] are presented in Table VII. Table VIII, extracted from a recent publication of Cerchar,[4] gives some comparative results of investigations dealing with a standard type of Baum jig and a modern type of feldspar jig. The influence of sizes on actual values of specific gravity of separation and probable error should be noted in the various cases presented.

Conclusions

A complete analysis and discussion of the results presented here would be impracticable. Some points, however, are well established: 1) The feldspar jig can treat efficiently all sizes of coal below ⅜ in. and down to ½ mm. 2) Efficient and accurate separations are possible even at low gravities. 3) Excellent total organic efficiencies are possible by rewashing of the intermediate products. 4) Regularity and consistency of separation are insured by the use of extra-sensitive automatic controls. 5) No definite figure of probable error or of efficiency can be given to qualify the feldspar jig, but this is true for all processes. 6) The most important factor to consider when comparing various cleaning processes is the size range of the feed.

On the Continent today the feldspar jig is the most popular process for cleaning fine coals (⅜ in. to ½ mm). The Heavy Media process is considered the most accurate, although the range of application is limited to sizes over ⅜ in. for average Continental practice. For the sizes below ½ mm, froth flotation is generally used, or simply flocculation.

Acknowledgments

The author expresses appreciation to Centre d'Etudes et Recherches des Charbonages de France and to Christian Wolf, president, Preparation Industrielle des Combustibles, for abundant and useful data. He also wishes to thank the staff of the McNally Pittsburg Mfg. Corp. for their valuable technical assistance in the preparation of this paper.

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Mineral Flotation with Ultrasonically Emulsified Collecting Reagents

With the aid of emulsifiers, intense high-frequency sound waves are capable of emulsifying any collector in water. The data show also that ultrasonically emulsified collectors are more effective in floating minerals than the nonemulsified collectors.

by S. C. Sun, L. Y. Tu, and E. Ackerman

THE use of ultrasonics in forming emulsions is not new. As early as 1927 Wood and Loomis[1] reported preparation of emulsions with ultrasonics. In 1935 Rschevkin and Ostrawsky[2] described the use of great ultrasonic power in producing fine emulsions of various oils and paraffin in water. Recently Oyama and Tanaka[3] employed ultra-emulsification to increase the effectiveness of sodium ethyl xanthate in flotation of chalcopyrite and galena.

An emulsion is a two-phase system consisting of two incompletely miscible liquids, the one being dispersed as finite droplets in the other. The dispersed liquid is known as the *internal* or *discontinuous* phase, and the surrounding liquid is termed the *external* or *continuous* phase. There are two types of emulsions; one is oil-in-water (O/W) and the other water-in-oil (W/O). The word *oil* refers to the liquid other than water. Circumstances exist in which the emulsion type is not clearly defined, and the internal and external phases both contain portions of the opposite phase. This is said to be a dual emulsion. Among the many hypotheses[4, 5a, 6] proposed for the formation of emulsions, the Bancroft's adsorbed film or double interfacial tension theory is widely accepted. Bancroft [7, 8] deduced that in the process of emulsification the interfacial tension between oil and water is lowered by the formation of an emulsifying film, which contains the adsorbed molecules and/or ions from the emulsifying agent and the two liquids. This film has two interfacial tensions, one with the water and the other with the oil, which are not necessarily equal. The difference in interfacial tension between the two surfaces of the film is chiefly responsible for forming different types of emulsions. For example, if the interfacial tension between water and film is less than that between oil and film, the film will become convex on the water side, thereby tending to form an oil-in-water emulsion. On the other hand, if the interfacial tension between water and film is greater than that between oil and film, the film will become concave on the water side, thereby tending to make a water-in-oil emulsion. In line with this theory, emulsifying agents soluble in water have the tendency to form oil-in-water emulsions, while those soluble in oil form emulsions of the reverse type.

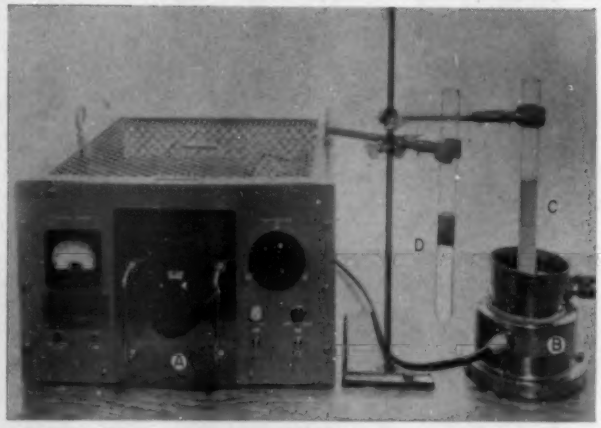

Fig. 1—Apparatus for intermittent emulsification. A—Hypersonic generator. B—Hypersonic transducer bowl. C and D—Glass tubes. Note that glass tube D shows two immiscible liquid phases of rosin amine D and water and that glass tube C shows the ultrasonic emulsion of these two liquids.

Apparatus and Experimental Procedure: The ultrasonic apparatus shown in Fig. 1 consisted of a hypersonic generator (A), Brush Development Co. model Bu-204; a hypersonic transducer bowl (B) whose resonant frequency is 400 kc per sec; and a round-bottomed glass tube (C) of 2.2 cm ID and 21 cm in length. The acoustical output power of the hypersonic transducer bowl was standardized with a Hewlett Packard vacuum tube voltmeter, model 410B, across the hypersonic generator output. The glass tube, containing the materials to be emulsified, was placed 1 cm above the central surface of the transducer bowl, which was filled with water as shown in Fig. 2.

Ultrasonic emulsification was performed in three steps, although a one-step method has been used: 1) emulsifying the predetermined amounts of col-

S. C. SUN, Member AIME, L. Y. TU, and E. ACKERMAN, are Associate Professor of Mineral Preparation, Research Associate of Engineering Mechanics, and Assistant Professor of Physics, respectively, The Pennsylvania State University, University Park, Pa.

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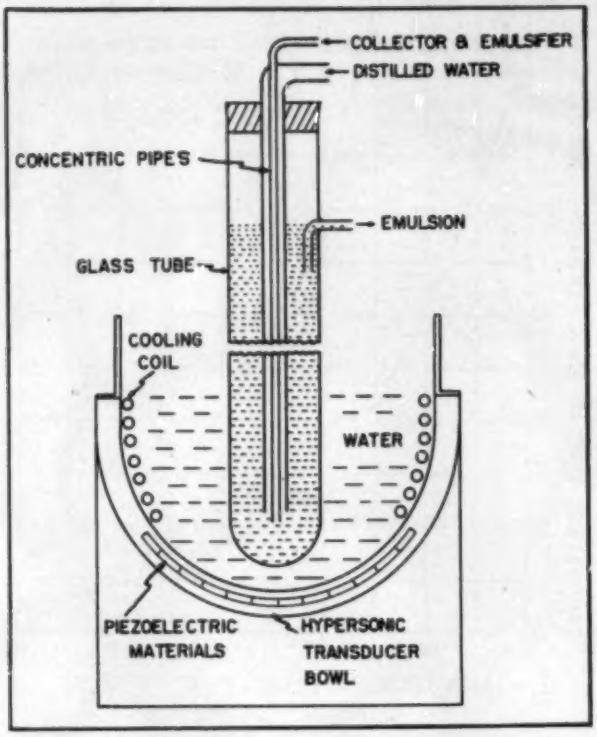

Fig. 2—Apparatus for continuous emulsification.

lector and emulsifier in 1 cc of distilled water; 2) adding 10 cc of distilled water and emulsifying the diluted emulsion; and 3) increasing the volume to 30 cc with distilled water and emulsifying the diluted emulsion. The time ratio of the ultrasonic emulsification used in steps 1, 2, and 3 was about 3:2:1 respectively. The one-step method consisted of placing the total 30-cc mixture of the ingredients to be emulsified into the glass tube and emulsifying it until completion. An apparatus for continuous emulsification, as shown in Fig. 2, was also tested. The results, not presented, indicated that continuous emulsification is possible with this apparatus by the focusing of sound waves at the outlet of the two concentric pipes.

In addition to the hypersonic transducer bowl, other types of ultrasonic generators were tested and proved satisfactory. These included: 1) a crystal type Ultrasonorator, model SL-520, with resonant frequencies of 400, 700, 1000, and 1500 kc per sec; 2) a powerful high frequency siren;[9] 3) an electromagnetic transducer, St. Clair Type;[10] 4) a Raytheon magnetostrictive oscillator.[11] No comparisons were made of the relative efficiencies of these other types of generators.

Ultrasonic Emulsification of Collectors: The experimental results as given in Table I and Figs. 3-5 show that the ultrasonic emulsification of collectors in water can be facilitated either by improving the hydrophile-lipophile balance[12] or hydrophilic property of the collector, or by increasing the intensity of the sound waves, or both. Emulsification is retarded or even inhibited whenever the collector is highly lipophilic and/or the sound intensity is low. Results also show that emulsification of a collector in water without the presence of an emulsifier is much more easily performed at a low concentration than at a high concentration of the collector.

Concerning hydrophile-lipophile balance, termed HLB, Table I indicates that without the presence of emulsifier the highly lipophilic collectors exemplified by Nujol and Armeen 18D are much more difficult to emulsify in water than the highly hydrophilic collectors represented by potassium ethyl xanthate and Turkey red oil. This difference is attributed to the fact that a lipophilic collector having a low HLB is practically water-repellent and has a high interfacial tension with water, whereas a hydrophilic collector having a high HLB is practically water-avid and has a low interfacial tension with water. This is in agreement with the fact[13] that a low interfacial tension assists the formation of an oil-in-water emulsion. Fig. 3 and Table I show that a suitable emulsifier or a combination of emulsifiers promotes the formation of an emulsion and aids the stability. This is due to the fact that emulsifiers having a high HLB are capable not only of solubilizing the collector and lowering the interfacial tension between the collector and water but also of protecting the dispersed particles of the collector from coalescence. As mentioned before, emulsifiers with a high HLB are hydrophilic and tend to form O/W emulsions, whereas those with a low HLB are lipophilic and tend to form W/O emulsions.

Regarding sound intensity, Fig. 4 indicates that at a constant sound frequency the emulsifying power of ultrasonics increases with an increase of the intensity of the sound waves. This can be explained by the fact that the occurrence of cavitation, which is responsible for the mechanism[13] of ultrasonic emulsification, is enhanced by the increase of sound intensity. When intense sonic energy is sent through a system of two liquids to be emulsified, the molecules of the liquids are violently agitated and torn apart, causing the formation of cavities. The collapse of cavities an instant after formation may result in an effective pressure equivalent to several thousand atmospheres.[13, 14] Such enormous forces could account not only for mixing the liquids but also for breaking up or dispersing the internal phase in the external phase of the emulsion, so that the dispersed particles are sufficiently small to prevent coalescence. It should be noted that the indicated sound intensities of Table I and Fig. 4 were calculated by multiplying the measured electrical input power of the transducer with the conversion factor of 0.46. The sound intensity at the focus may be several hundred times larger than the values thus calculated, which are valid only at the bowl surface.

Considering the concentration of collector, Fig. 5 shows that for a given sound intensity, the acoustical time for emulsifying oleic acid in water without the aid of an emulsifier increases with an increase of oleic acid. This is also true for other collectors, particularly those of low solubility. An explanation of this phenomenon may be found in the facts that 1) the excess amount of collector, which is not water-soluble and has to be emulsified by sound waves, increases with higher concentration of the collector; 2) the viscidity of the resulting emulsion, which increases with higher concentration of the emulsion, may become high enough to retard the formation of cavitation after a certain portion of the collector is emulsified, and emulsification of the remaining non-emulsified portion of the collector proceeds at a much lower rate; and 3) the dispersed particles of collector tend to be more coalescent in a concentrated emulsion than in a dilute emulsion. In contrast, in the presence of emulsifiers and intense sound waves, emulsions of high concentration can be prepared from any collector, regardless of its solu-

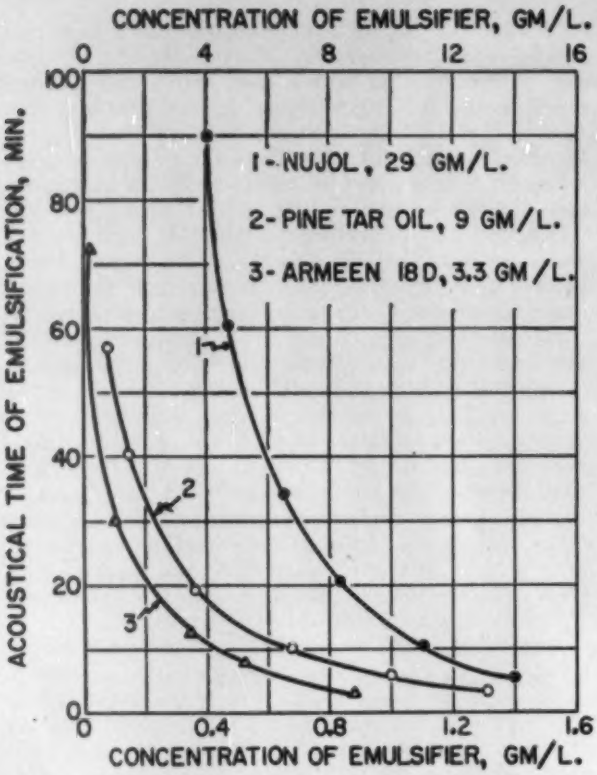

Fig. 3—Effect of the concentration of an emulsifier on the acoustical time of ultrasonic emulsification at 400 kc per sec frequency and 1.19 watts per cm² acoustical output power. Concentration of emulsifier Aerosol OS (Curve 2) is shown by top scale; concentration for Aerosol OT (Curve 1) and HCl (Curve 3) is shown on lower scale.

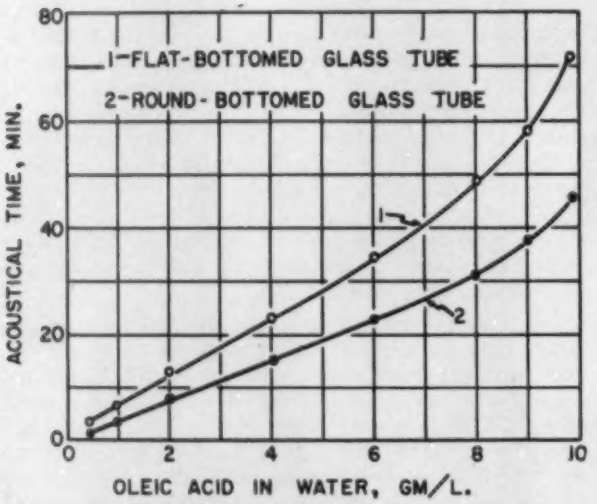

Fig. 5—The acoustical time for producing oleic acid-in-water emulsions at various concentrations of oleic acid and with different shapes of glass tube, tested with a hypersonic transducer bowl of 400 kc per sec, sound frequency, and 1.2 watts per cm² acoustical output power.

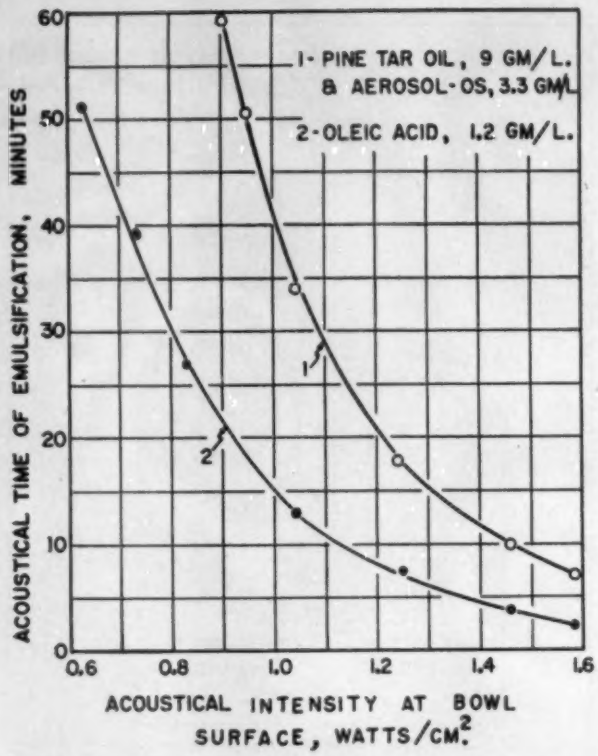

Fig. 4—Effect of the acoustical intensity at bowl surface on acoustical time for emulsifying collectors in water at a constant frequency of 400 kc per sec.

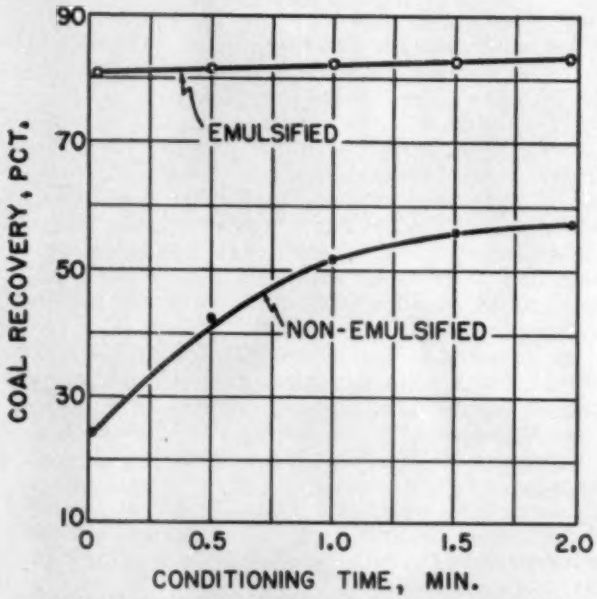

Fig. 6—Flotation of a bituminous coal with an ultrasonically emulsified and nonemulsified collector and a 0.09 lb per ton pine oil frother under various conditioning times. Note that the amount of collector used for each flotation test was 0.4 lb per ton paraffin wax, 0.04 lb per ton Span 40, and 0.04 lb per ton Tween 40.

bility, as indicated in Table I and Figs. 3 and 4.

Fig. 5 shows that a round-bottomed glass tube is more effective in ultrasonic emulsification than a glass tube of the same size with a flat bottom. This is because there is less reflection of the incident sound waves with the former than with the latter, as can be visualized from the concave shape of the piezoelectric materials of the transducer bowl.

Flotation: Tests on the flotation of minerals with ultrasonically emulsified and nonemulsified collectors were performed in a laboratory Fagergren flotation machine. Except where otherwise stated, the amount of mineral used for each test was 300 g. Results, as given in Table II and Fig. 6, were obtained by first floating a mineral with a collector ultrasonically emulsified in the presence of an emulsifier,

Table I. Ultrasonic Emulsification of Collectors in Water with a Hypersonic Transducer Bowl at a Constant Frequency of 400 Kc Per Sec

Test No.	Collector		Emulsifier		Acoustical Intensity‡ at Bowl Surface, Watts per Cm²	Acoustical Time of Emulsification, Min	Number of Emulsifying Stages	Approximate Stability of Resulting Emulsion, Days	Maximum Concentration of Collector Tested, G Per Liter
	Name	Concentration, G Per Liter	Name	Concentration, G Per Liter					
1	Paraffin wax	15.0	Span-60	2.7	1.68	35	3	>120	150
			Tween-60	2.7					
1a	Bee wax	4.2	Lissapol-N	8.9	1.68	23	3	>120	150
2	Light coal tar*	3.5	Aerosol-OS	18.3	1.68	42	3	5	7
			Lissapol-N	17.6					
3	Nujol	29.1	Lissapol-N	2.5	1.19	10	3	>15	290
3A	Nujol	45.0	Span-40	0.6	1.19	12	3	>15	290
			Tween-40	0.6					
4	Unitol**	5.5	NaOH	0.4	1.68	5	3	>120	25
			Aerosol-OS	1.0					
4A	Unitol**	5.5	Aerosol-OS	1.19	1.32	18	3	>30	25
5	Armeen 18D***	3.3	O	0	1.68	30	3	2	5
5A	Armeen 18D***	3.3	Hcl	0.4	1.68	12	3	>20	10
6	Armeen 16D***	3.3	O	0	1.19	25	3	2	7
6A	Armeen 16D***	3.3	Hcl	0.2	1.19	9	3	>20	14
7	Reagent 444*	4.0	O	0	1.68	25	3	2	30
8	Aerofloat 33†	3.5	Aerosol-OS	1.0	1.68	22	3	4	35
9	Aerofloat 242†	5.0	O	0	1.68	20	3	2	10
9A	Aerofloat 242†	5.0	Aerosol-OS	0.8	1.68	14	3	5	15
10	Pine tar oil‡	9.0	Aerosol-OS	3.3	1.68	6	3	>120	50
10A	Pine tar oil‡	9.0	Aerosol-OT	4.3	1.68	12	3	>60	25
10B	Pine tar oil‡	4.5	Lissapol-N	4.1	1.68	12	3	>30	15
11	Rosin amine D§	3.0	O	0	1.19	18	3	2	10
11A	Rosin amine D§	3.0	Hcl	0.2	1.19	6	3	>20	15
12	Oleic acid	2.0	O	0	1.68	5	3	3	12
12A	Oleic acid	2.0	O	0	1.19	9	3	3	10
13	Lauryl amine	3.0	O	0	1.68	5	1	5	35
14	K-eth.-X	10.0	O	0	1.19	7	3	5	30
15	Turkey red oil	10.0	O	0	1.19	3	1	7	80

*Barrett Div., Allied Chemical and Dye Corp.
** Union Bag and Paper Corp.
*** Armour Co.
† American Cyanamid Co.
‡ Newport Industries Corp.
§ Hercules Powder Co.
‖ Calculated.

Table II. A Comparison Between the Ultrasonically Emulsified and Nonemulsified Collectors in the Flotation of Minerals

Test No.	Collector		Emulsifier		Mineral		pH	Conditioning Time, Min	Frother,** Lb Per Ton	Flotation Time, Min	Flotation Recovery, Pct	
	Name	Concentration, Lb Per Ton	Name	Concentration, Lb Per Ton	Name	Particle Size, Mesh					Ultrasonically Emulsified Collector	Nonemulsified Collector
1	Paraffin wax	0.4	Span-60	0.04	Bituminous	−35	7.7	0.0	PO., 0.09	3	80.5	27.1
			Tween-60	0.04	coal*							
1A	Paraffin wax	0.4	Span-60	0.04	Bituminous	−35	7.7	1.0	PO., 0.09	3	82.2	51.5
			Tween-60	0.04	coal*							
1B	Paraffin wax	0.4	Span-60	0.04	Bituminous	−35	7.7	2.0	PO., 0.09	3	83.0	85.9
			Tween-60	0.04	coal*							
2	Light coal tar	0.4	Aerosol-OS	0.89	Bituminous	−35	7.5	0.5	PO., 0.09	1	83.6	40.5
			Lissapol-N	1.12	coal*							
2A	Light coal tar	0.4	Aerosol-OS	0.89	Bituminous	−35	7.5	0.5	PO., 0.09	2	94.2	47.3
			Lissapol-N	1.12	coal*							
3	Nujol	0.4	Span-40	0.003	Bituminous	−35	8.5	0.0	PO., 0.09	3	66.1	44.2
			Tween-40	0.003	coal*							
3A	Nujol	0.4	Span-40	0.003	Bituminous	−35	8.5	1.0	PO., 0.09	3	69.9	56.1
			Tween-40	0.003	coal*							
3B	Nujol	0.4	Span-40	0.003	Bituminous	−35	8.5	2.0	PO., 0.09	3	71.8	61.1
			Tween-40	0.003	coal*							
4	Unitol	0.5	NaOH	0.04	Cassiterite	−100	6.2	2.0	HA., 0.09	3	94.5	28.6
			Aerosol-OS	0.10								
4A	Unitol	0.5	Aerosol-OS	0.13	Siderite	−65	6.2	2.0	HA., 0.09	1	37.4	21.6
4B	Unitol	0.5	Aerosol-OS	0.13	Siderite	−65	6.2	2.0	HA., 0.09	3	48.0	26.2
5	Armeen 18D	0.08	HCl	0.0003	Quartz	−100	6.2	2.0	HA., 0.09	2	82.9	69.6
6	Armeen 16D	0.30	HCl	0.0003	Siderite	−65	6.2	2.0	HA., 0.09	2	30.9	13.4
7	Reagent 444	0.10	O	0	Sphalerite	−100	7.0	2.0	HA., 0.09	3	32.1†	23.4†
8	Aerofloat 33	0.08	O	0	Galena	−100	7.0	2.0	HA., 0.09	2	65.8	52.9
9	Aerofloat 242	0.12	O	0	Galena	−100	7.0	2.0	HA., 0.09	2	97.6	86.2
10	Pine tar oil	0.36	Aeorosol-OS	0.09	Quartz	−100	6.2	2.0	HA., 0.03	3	71.3‡	41.3‡
10A	Pine tar oil	0.36	Aeorosol-OS	0.09	Siderite	−65	6.2	2.0	HA., 0.03	3	53.2‡	27.1‡
11	Rosin amine D	0.38	O	0	Zircon	−200	7.3	2.0	HA., 0.03	1	90.8‖	48.4‖
11A	Rosin amine D	0.38	O	0	Zircon	−200	7.3	2.0	HA., 0.03	2	92.7‖	60.2‖
12	Oleic acid	0.12	O	0	Zircon	−200	6.7	2.0	HA., 0.03	2	55.9‖§	28.7‖§
13	Lauryl amine	0.10	O	0	Quartz	−100	7.5	2.0	HA., 0.09	1	93.6	82.7
14	K-eth.-X	0.08	O	0	Galena	−100	7.0	1.0	HA., 0.09	1	92.5	81.6
15	Turkey red oil	0.50	O	0	Bituminous coal*	−35	7.5	0.5	PO., 0.09	2	90.4	83.1

* Bituminous coal was obtained from the Buckeye Coal Co., Nemacolin, Pa.
** PO., pine oil; HA., hexyl alcohol.
† 0.05 lb per ton $CuSO_4$ was used as activator.
‡ 0.25 lb per ton $CuSO_4$ and 800 gm mineral were used respectively as activator and flotation feed.
§ 0.25 lb per ton sodium silicate and 800 gm mineral were used respectively as activator and flotation feed.
‖ The amount of mineral used for each flotation test was 750 gm.

Table III. Effect of Ultrasonic Emulsification on the Frothability of Collectors, Tested at 19.2 Mg Per Liter Concentration, 71.6 CC Per Sq CM Per Min Rate of Aeration, and 7.0 pH Value

Collector	Volume of Froth Measured at End of 4-Min Time of Aeration, Cc Per Cm²	Stability of Froth Measured at End of 6-Min Time of Aeration, Sec Per Cm*
Ultrasonically emulsified lauryl amine	0.5	13.6
Nonemulsified lauryl amine	Trace	22.1
Ultrasonically emulsified oleic acid	0.4	16.7
Nonemulsified oleic acid	0.2	17.5

* The stability of froth was calculated by dividing the time elapsed until the froth disappeared by the height of the froth column and is expressed in seconds per cm.

and then floating the mineral with the same collector and emulsifier without either ultrasonic emulsification or premixing. Results show that ultrasonic emulsification can be employed for: 1) converting solid hydrocarbons into oily collectors; 2) increasing the collecting power of collectors, particularly the insoluble and slightly soluble ones; and 3) shortening the conditioning time of collectors. Furthermore, collectors of high viscosity and low solubility can be dispersed in water to form fluid emulsions by means of ultrasonic emulsification and thus become suitable for direct feeding to the flotation cell or conditioning tank. The fluidity and concentration of the collector-in-water emulsions can be further adjusted by addition of water. As a result ultrasonic emulsification is expected to be useful not only for reducing consumption of collecting reagents and shortening conditioning time, but also for eliminating the difficulty of using and handling the highly viscous collectors.

It is postulated here that the above flotation phenomena are chiefly caused by the reduction of droplet size and the increase in hydration of collectors through ultrasonic emulsification. Considering droplet size, the very fine droplets of an ultrasonically emulsified collector, having a large specific surface area and a high degree of unsaturation, are capable not only of contacting more mineral particles but also of being more reactive in a flotation cell than the relatively coarse droplets of the same collector subjected to no ultrasonic emulsification. Regarding hydration, the fine droplets of a collector-in-water emulsion, having an external phase of water or colloid hydrate, are dispersible or soluble in water and consequently can be effective in the mineral pulp of a flotation cell with a much shorter conditioning time than the same collector subjected to no ultrasonic emulsification. Furthermore, the frothability of some of the frothable collectors, usually the less soluble ones,[15, 16] is also increased by the dispersing and hydrating effects of ultrasonic emulsification.

Experimental evidence in support of this postulate was established first by agitation of 2 liters of distilled water and 0.1 gm of collector in a laboratory Fagergren flotation cell for 2 min. The droplet size of the resulting solution was then determined with a high-power microscope, and finally the insoluble portion of the collector remaining on the liquid surface was estimated with a magnifying glass and suitable illumination. The data show that in the absence of ultrasonic emulsification the resulting solutions of the soluble collectors, such as potassium ethyl xanthate and reagent 301, are dominated by droplets of approximately 8 to 20 microns in size, although a few coarse droplets of 40 to 70 microns were also observed. In contrast, the resulting solutions prepared from the ultrasonic emulsions of the same collectors are dominated by droplets about 1 micron in size. This difference in droplet size becomes even more pronounced with the less soluble collectors such as Nujol, Unitol, and Armeen 18D. The data show also that the above cited less soluble collectors are only partly dissolved in water at the end of the agitation and that the ultrasonic emulsions of the same collectors are totally and instantaneously dissolved in water. Tests on the frothability of collectors were performed in a previously described frothmeter.[15, 16] The results, as given in Table III, show that ultrasonic emulsification increases the frothing power but decreases the froth stability of lauryl amine and oleic acid. Compared with the importance of droplet size and hydration, the role played by the frothing properties of the collectors is insignificant and can be neglected. This is particularly true when a frother is used in the flotation operation.

Summary

With the aid of emulsifiers, intense high-frequency sound waves are effective in emulsifying any collector in water. The ultrasonic emulsification of collectors in water can be facilitated either by improving the hydrophilic property of the collector, or by increasing the sound intensity, or both. In the absence of an emulsifier, the acoustical time for emulsifying a collector in water generally increases with an increase of the concentration of the collector. The ultrasonically emulsified collectors are more effective in the flotation of minerals than the nonemulsified collectors, particularly the insoluble and slightly soluble ones.

Acknowledgments

The writers wish to thank R. E. Snow for his kind assistance in flotation testing and in preparation of the drawings. They also wish to thank C. C. Hsiao and J. N. Brennen for their invaluable suggestions and cooperation and D. R. Mitchell, H. B. Charmbury, and R. C. Troxell for their active interest in this work.

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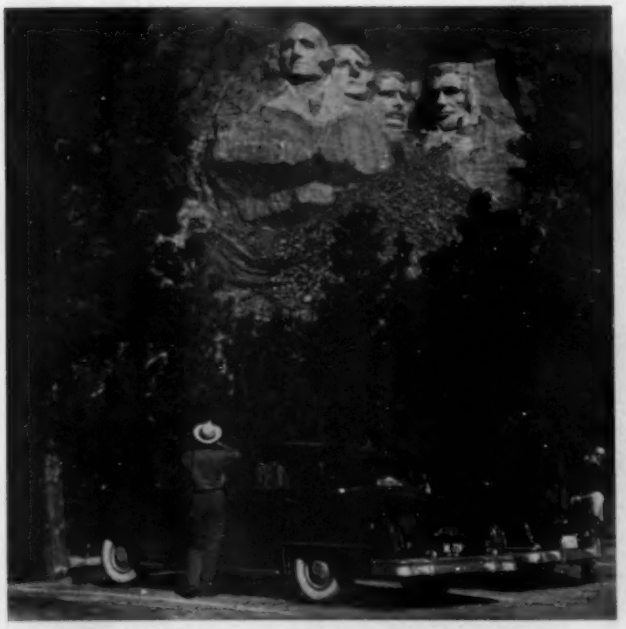
aime news

FALL 1955

MINING BRANCH

Minerals Beneficiation Div. Fall Meeting and Rocky Mountain Minerals Conference will be held concurrently at Salt Lake City, October 6 to 8. See MINING ENGINEERING, May 1955.

MEETING



Black Hills Section is host to the Regional Meeting of the MGGD at Rapid City, S. D., October 2 to 5. Mt. Rushmore is one of the places registrants will visit during field trips. See this issue for meeting details.

The Industrial Minerals Div. Fall Meeting is slated for Charlotte, N. C., October 27 to 29. Program Committee is planning a varied schedule. MINING ENGINEERING, August, will feature an advance story on the meeting.

Fall Regional Meeting

Black Hills Section to Play Host to Mining Branch Gathering at Rapid City, S. D., October 2 to 5

The Black Hills Section plays host to regional meeting of the Mining Branch October 2 to 5, with technical sessions scheduled for the South Dakota School of Mines and Technology at Rapid City on Monday and Tuesday.

Registrants who arrive for the first day of the meeting, Sunday, October 2, will have an opportunity to take part in mine and mill trips to Homestake Mining Co. operations at Bald Mountain and Lead. Homestake is one of the world's great gold producers. Center of Black Hills gold production is at Lead, situated only 3 miles from the legendary Deadwood. The frontier atmosphere is still part of the region.

Surface installations of the Homestake Mining Co. operation at Lead are shown in this aerial view. Lead, S. D., is visible at the bottom. Homestake is the largest gold producer in the Western Hemisphere and the fifth largest in the world. Homestake normally mines and mills 1.5 million tons of ore annually.

Opportunity to Visit Homestake Mine and Mill

Set amidst this historic background are mile-high golf courses. Teaming trout streams and wooded mountain scenery are much the same as when Wild Bill Hickok and Calamity Jane rode the trail.

Homestake was in operation when the Sioux roved the land, and when the prospector, ox team, and pioneer were winning the West. During the 77 years that Homestake has operated the mine has produced 21.5 million oz of gold from 78 million tons of ore. Current production is at a rate of 4300 tpd.

In addition to a tour of the underground and aboveground installations at Homestake, AIME visitors will be company guests at a buffalo barbecue at the end of the tour. Guests will see the headframe, collar, and hoistroom of the Yates shaft, which has been recently deepened to 4850 ft. A skip pocket is located below that depth.

Most of the company visitors don't get a chance to go underground. AIME guests, however, will see the major mining operations such as drifting, stoping, sand backfilling, and the allied activities that are part of underground work.

An underground miner at Homestake drills into solid ore with a lightweight jackhammer mounted on an aluminum air-feed leg, using treaded drill rod and tungsten carbide insert bit. Black Hills meeting visitors will get a chance to go underground at Homestake.

Welcoming Luncheon

One of the outstanding events on Monday, October 3, will be the Welcoming Luncheon, with Joe Foss, South Dakota's Governor, greeting the registrants. Other speakers will be Don L'Esperance, Mayor of Rapid City; F. L. Partlo, President, South Dakota School of Mines and Technology; and Renaldo D. Gallo, Chairman, Black Hills Section.

The morning and afternoon will be taken up with technical sessions at the School of Mines and Technology. Some of the papers to be presented are: "Geology of the Black

Hills," with Kodachrome slides; "Commercial Flotation of Spodumene from Pegmatite of the Black Hills, South Dakota"; "Thick Seam Mining at Wyodak Coal Co."; "Geologic Environment and Distribution of Mineable Pegmatites in the Southern Black Hills"; and "Geophysical-Geochemical Prospecting for Uranium."

Technical Sessions

Other papers will cover minerals in the River Basin development, mining methods at Homestake, early Black Hills metallurgical history, coal production of ammonia synthesis gas from lignite in an annular retort gasifier, the geology of the northern Black Hills bentonite district, and mining and milling at the Bald Mountain Mining Co.

There will also be a panel discussion on "What Should be the Future Objectives of Mineral Industry Education?"

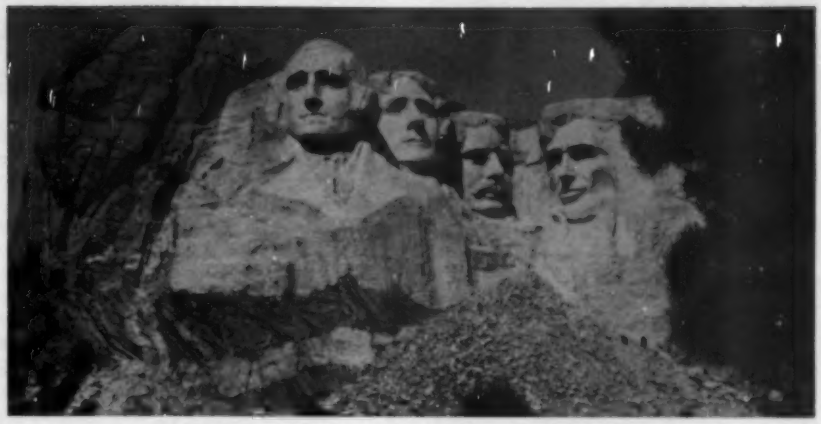
October is the ideal field trip time in the Black Hills. Trips have been planned to include interests of the entire family. If possible, private cars will be used exclusively, but buses will be available if needed.

Northern Black Hills Field Trip

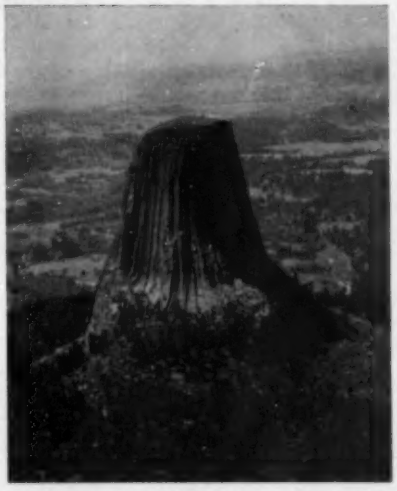
One trip will be to the northern Black Hills. The morning will be devoted to inspection of the clay industry in the Belle Fourche vicinity. First stop will be at the pit and plant of the Black Hills Clay Products Co., only ceramic brick and tile producer in the area.

Registrants will also have an opportunity to see all phases of stripping, mining, hauling, grinding, and packaging of bentonite at one of the modern operations west of Belle Fourche.

Following lunch, the group will go west through the north end of Bear Lodge Mountains, with a brief stop at the Devil's Tower National Monument. Inspection will be made of one of the small uranium operations near Carlile Junction or New Haven, Wyo. The group will return by way of Spearfish, home of the Black Hills Passion Play.



Both field trips to the southern Black Hills will stop at Mt. Rushmore.



The Thursday trip to the northern Black Hills will take registrants to the Devil's Tower, projecting 800 ft above the Wyoming plains.

Southern Black Hills Field Trips

Another tour on Wednesday goes directly from Rapid City to the Shrine of Democracy at Mt. Rushmore. A visit will also be made to one of the pegmatite mines at Keystone, probably the Etta. Geologists taking the tour are advised to bring their picks. A visit is planned to the mica processing plant at Custer.

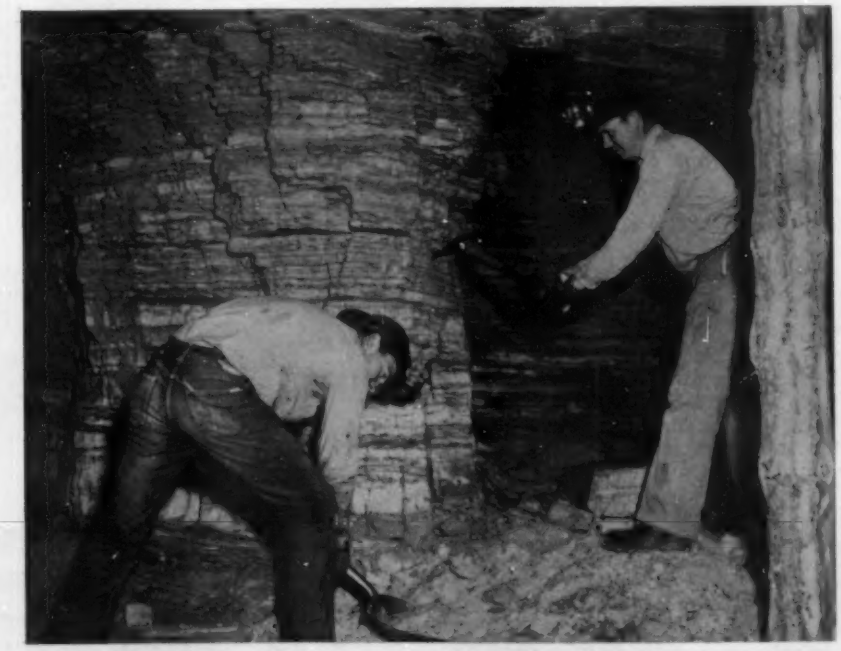
After lunch the party goes directly to the carnotite mining area north of Edgemont, Fall River County. At least one large mining operation will be visited under guidance of Atomic Energy Commission and U. S. Geological Survey personnel.

A third tour also goes directly to Mt. Rushmore but sidetracks to the lithia flotation mill of the Lithium Corp. of America at Hill City, and one of the International Minerals & Chemical Corp. feldspar grinding plants at Keystone or Custer. Visits will also be made to the mica processing plant at Custer and the uranium mining area at Edgemont.

Badlands Trip

A fourth trip takes visitors into the badlands under the direction of J. R. Macdonald of the Museum of Geology. The party will visit Sheep Mountain in the Badlands National Monument and fossil collectors will have a chance for some specimens under not too strenuous conditions. Lunch will be served at Cedar Pass. The group returns to Rapid City by way of the much-publicized Wall Drug Store.

If interest warrants, a special stratigraphic and structural trip in the Black Hills will be arranged.



The alternate trips to the southern Black Hills are scheduled to visit active uranium operations in the Edgemont area. The men are working at a face of the Virginia "C" mine north of Edgemont.

1956 AIME Nominations Slate Announced

For President-Elect

GROVER J. HOLT

Grover J. Holt, general manager of the ore mining dept., Cleveland-Cliffs Iron Co., Ishpeming, Mich., has been nominated for the presidency of AIME in 1957. Mr. Holt was born in Northwood, N. D., on July 30, 1894. He enrolled in mining engineering at the University of North Dakota, received a bachelor of science in mining engineering in 1916 and later received the degree of mining engineer from that university. Mr. Holt was engaged in postgraduate work at the University of Utah from 1916 to 1917. This work was in connection with a research fellowship in metallurgy and ore dressing. He spent a short time following completion of this fellowship work as superintendent of the Basin Metal Mining Corp., Ouray, Utah. During World War I, Mr. Holt entered the U. S. Army Engineer Corps at Corpus Christi, Texas, entered officers' training, and served in France.

During 1919 he was employed by the Bunker Hill & Sullivan Mining & Smelting Co., Kellogg, Idaho. In 1920 he joined the U. S. Steel Corp. at Chisholm, Minn., remaining as a mining engineer until 1928. For one year he was chief engineer and superintendent of the Manganiferous Iron Co. of Crosby, Minn. From 1930 to 1942 he was located at the St. Paul office of Butler Brothers as assistant to the vice president.

Mr. Holt joined Cleveland-Cliffs in 1942 as chief engineer. He was promoted to manager of Minnesota mines in 1950 and was appointed general manager of mines for Minnesota and Michigan in 1953.

Mr. Holt has been extremely active in AIME and aided in the formation of the Minerals Beneficiation Div. He was Chairman of that division, and also Chairman of the Minnesota Local Section and the annual fall meeting of the MBD held in Hibbing in 1953. He served as a member of the Nominating Committee and was appointed Chairman of that committee in 1953.

For Vice Presidents

L. E. ELKINS

Lloyd E. Elkins, production research director, Stanolind Oil & Gas Co., has been nominated as Vice President and Director of AIME. Born at Golden, Colo., in 1912, he received his degree in petroleum production engineering from the Colorado School of Mines. Following graduation he was employed by the Stanolind Oil & Gas Co. at Wink, Texas, and has risen steadily during his years with the company. In 1948 Mr. Elkins was selected to attend the advanced management program at the Harvard Graduate School of Business Administration. He has been active in the Petroleum Branch of AIME of which he was Chairman in 1949.

J. L. GILLSON

Joseph Lincoln Gillson became an AIME Member in 1923. He is now nominated as a Vice President. He received his B.S. and M.A. degrees from Northwestern and his M.S. from MIT, where he was an associate professor in 1928. The following year he returned to Northwestern as associate professor of economic geology. In 1930 he joined E. I. du Pont deNemours & Co., Wilmington, Del. Mr. Gillson was Chairman of the AIME Industrial Minerals Div. in 1947 and was also Chairman of the AIME Committee on Democratization. He was a Vice President of AIME from 1951 to 1954.

For Directors

R. B. CAPLES

R. B. Caples has been nominated as a Director of AIME. He was born in Glasgow, Mo., in 1888 and graduated from the Missouri School of Mines in 1919, where he received an honorary degree of Doctor of Engineering in 1948. Mr. Caples started his professional career with the Federal Mining & Smelting Co. in the

Edward G. Fox, Chairman of the Nominating Committee, has announced nominations for President-Elect, Vice Presidents, and Directors for 1956. As provided in Art. IX, Sec. 2 of the bylaws, 25 Members or Associate Members may sign and transmit to the Secretary's office prior to September 1, "any complete or partial ticket of nominees," should they wish other candidates to be considered.

In such instance, a letter ballot will be forwarded to all Members in good standing in the United States, Canada, and Mexico, tabulating both the official ballot and any supplementary nominations. If no supplementary nominations are thus received, no letter ballot will be printed, and nominees on the official ballot shall be declared duly elected at the meeting of the Board of Directors or the Executive Committee in November.

Coeur d'Alene district in Idaho and shortly thereafter entered the employ of the Anaconda Copper Mining Co. He was first employed in the testing dept. of the Anaconda Reduction Works, working in collaboration with Messrs. Frederick Laist, F. F. Frick, and James O. Elton in the development of the electrolytic zinc process during 1916 to 1924, as well as the basic process for the Anaconda phosphate plant. In 1918 he became superintendent of the Great Falls, Mont., plant and was made manager in 1941. Mr. Caples is presently president and director of the Anaconda Aluminum Co., New York, N. Y. He has served on various committees of the Extractive Metallurgy Div. of the Institute, including the Executive Committee and has just completed a three-year term as AIME Director.

C. R. DODSON

Charles R. Dodson has been nominated as Director for a three-year term. Mr. Dodson is assistant vice president at the First National City Bank of New York, New York. He was born in Washington, D. C. in 1907 and graduated from University of Maryland and Massachusetts Institute of Technology. He was at the University of California from 1932 to 1934, engaged in graduate work in mathematics, physics, and engineering. In 1944 Mr. Dodson enrolled at the University of Southern California for a course in supervision and management. During his career he has been associated with the General Electric Co., York Ice Machinery, and Standard Oil Co. of California. Mr. Dodson has been active in the petroleum industry for 19 years. From 1947 to 1954 he was engaged in consulting and teaching. In March 1954, Mr. Dodson joined the petroleum dept. of the First National City Bank of New York.

ANDREW FLETCHER

Andrew Fletcher, president of St. Joseph Lead Co., has been nominated as a Director of AIME for three years. Mr. Fletcher, who was born in 1895 in New York City, was educated at Hill School and the Sheffield Scientific School of Yale University, where he received a Ph.B. in mechanical engineering. In 1949 the University of Missouri conferred upon him an honorary degree of Doctor of Engineering. In addition to being president of St. Joseph Lead Co., he is also president of the Mine LaMotte Corp., and Bonne Terre Farming & Cattle Co. He is vice-president of Missouri-Illinois RR Co. and director of the America-Hawaiian Steamship Co. He has been on the Board of AIME for many years and has been Treasurer and President.

C. R. KUZELL

C. R. Kuzell, vice president in charge of western activities for the Phelps Dodge Corp., Douglas, Ariz., has been nominated as an AIME Director for a three-year term. Mr. Kuzell is also president of the Apache Powder Co., Benson, Ariz. He is a graduate of the Case School of Applied Science. In 1910 Mr. Kuzell joined the Anaconda Copper Mining Co., Great Falls, Mont. He was transferred to Anaconda as superintendent of reverberatory smelting in 1914. From 1918 to 1935 Mr. Kuzell was associated with the United Verde Copper Co., Clarkdale, Ariz., where he was smelter superintendent and later became general superintendent. United Verde became a branch of Phelps Dodge Corp., and Mr. Kuzell was manager from January 1940 to 1944. He was then appointed director of labor relations and consulting metallurgist for Phelps Dodge at Douglas. He was named assistant general manager in 1946 and held this position until 1952 when he became general manager. Mr. Kuzell has held his present position since January 1955. Mr. Kuzell holds membership in the American Mining Congress, American Chemical Society, and Mining and Metallurgical Society of America. He has been an AIME Member since 1912. The Arizona Section named him Chairman in 1946 and he was also Chairman of the Committee on Reduction and Refining of Copper in 1933.

F. J. MEEK

Fred J. Meek, plant engineer for the American Zinc Co. of Illinois, E. St. Louis, Ill., has been nominated for a three-year term as Director of AIME. Mr. Meek has served the St. Louis Local Section as Secretary, Chairman, Council Delegate, and Secretary for the 1951 Annual Meeting Committee. He was Chairman of the Council of Section Delegates in 1954 and served on the National Membership Steering Committee and Nominating Committee in 1954. Mr. Meek attended the University of Illinois taking mechanical engineering and later mining engineering courses. His schooling was interrupted by World War I. He entered the Air Force in 1917 and received his commission as a second lieutenant. He returned to mining work with the Egyptian Coal & Mining Co. and O.K. Coal Co. In 1932 Mr. Meek joined the Eagle-Picher Lead Co., Hillsboro, Ill., later transferring to the mining and smelting div. He became plant engineer for the American Zinc Co. of Illinois in 1941 at E. St. Louis, Ill. Continuing in that position he was put in charge of engineering and later became superintendent of the power and mechanical depts.

G. F. MOULTON

Gail F. Moulton, presently a Director of AIME has been renominated for a three-year term. Born in Chicago, he was graduated from the University of Chicago in 1920. Mr. Moulton has had extensive experience in the petroleum industry, served as assistant professor at University of South Dakota, and headed the petroleum section of the Illinios State Geological Survey. He was later employed by United Gas Co., Electric Bond & Share Co., and Ralph E. Davis, Inc. Late in 1951, he joined Rockefeller Brothers Inc. as a consultant. A former Vice Chairman of the Petroleum Branch, Mr. Moulton has served on many AIME committees and for the last year has been Treasurer.

Mining Branch Nominations for 1956

This is the complete list of officers nominated for the Mining Branch and its Divisions. Nominations of AIME officers for 1956 appear on page 664.

Minerals Beneficiation Div.

Chairman, Norman L. Weiss, American Smelting & Refining Co.; Associate Chairman, W. B. Stephenson, Allen-Sherman-Hoff Pump Co.; Regional Vice Chairmen, Nathaniel Arbiter, Columbia University, and Wayne L. Dowdey, Eimco Corp.; Secretary-Treasurer, H. R. Spedden, Union Carbide & Carbon Corp.

Mining, Geology, and Geophysics Div.

Chairman, Kenneth L. Cook, U. S. Geological Survey; Mining Subdivision Vice Chairman, Roger V. Pierce, Salt Lake City; Geology Subdivision Vice Chairman, D. M. Fraser, Bethlehem Steel Co.; Geophysics Subdivision Vice Chairman, H. V. W. Donohoo, U. S. Steel Corp.

Industrial Minerals Div.

Chairman, Raymond B. Ladoo, consultant, Newton, Mass.; Eastern Vice Chairman, John G. Broughton, New York State Science Service; Southeastern Vice Chairman, J. L. Weaver, American Cyanamid Co.; Mid-Continent Vice Chairman, John C. Frye, Illinois State Geological Survey; Rocky Mountain Vice Chairman, J. J. Norton, U. S. Geological Survey; Pacific Southwestern Vice Chairman, V. E. Scheid, University of Nevada; Pacific Northwestern Vice Chairman, M. T. Huntting, Washington Div. of Mines & Geology; Canadian Vice Chairman, Norman B. Davis, Consultant, Ottawa, Canada; Secretary-Treasurer, Robert M. Grogan, E. I. du Pont de Nemours & Co.; Executive Committee: John H. Weitz, Independent Explosives Co.; R. H. Jahns, California Institute of Technology; T. D. Murphy, U. S. Geological Survey; A. O. Bartell, Raw Materials Survey Inc.; and Richard Lund, Battelle Memorial Institute.

Mineral Economics Div.

Chairman, Clayton G. Ball, Paul Weir Co.; Vice Chairman, L. C. Raymond, Ford, Bacon & Davis Inc.; Vice Chairman, Henry T. Mudd, Los Angeles; Vice Chairman, Sheldon P. Wimpfen, Atomic Energy Commission; Secretary-Treasurer, A. H. Lindley, Jr., U. S. Bureau of Mines, Executive Committee (to 1957): A. O. Bartell, Raw Materials Survey Inc.; J. H. Ffolliott, Miami Copper Co.; and P. R. Turnbull, La-Gloria Corp.; (to 1958) E. W. Pehrson, U. S. Bureau of Mines; F. R. Milliken, Kennecott Copper Co.; and G. C. Monture, Dept. of Mines & Technical Surveys (Ottawa, Canada); (to 1959) M. E. Volin, U. S. Bureau of Mines; John D. Ridge, The Pennsylvania State University; and G. S. Borden, Standard Oil Co. of California.

Coal Div.

Chairman, Carl T. Hayden, Sahara Coal Co.; Chairman-Elect, Charles T. Holland, Virginia Polytechnic Institute, Secretary-Treasurer, David R. Mitchell, The Pennsylvania State University; Executive Committee (1956-1959): H. Eugene Mauck, Olga Coal Co.; Henry C. Rose, Pittsburgh Coal Co.; and James C. Gray, U. S. Steel Corp.

Mineral Industry Education Div.

Chairman, J. W. Stewart, University of Alabama; Vice Chairman, O. C. Shepard, Stanford University; Secretary-Treasurer, Thomas A. Read, University of Illinois; Executive Committee (1956-1959): Frank G. Miller, Stanford University; P. R. Bradley, Pacific Mining Co.; and F. T. Sisco, Engineering Foundation.

Around the Sections

• **The Washington, D. C., Section** made its annual field trip last June, this time to the Armco Steel Corp., Rustless Div., Baltimore. On arrival at the plant, the group was met by guides at the Rustless Employees' Club House. After a short talk describing the plant, the party was divided into small units for the actual tour. Lunch was served by the company.

• **The Southern Nevada Section** went on a field trip to the Blue Diamond Corp. through the courtesy of H. Lorenz Waldthausen, corporation manager. The visitors were shown through the extensive gypsum mining operations, at present open pit. They also saw the plant for manufacturing plaster board and other products.

• This year's winner of the Old Timers' award at Pennsylvania State University was George C. Trevorrow, Jr., of Verona, Pa., Student Associate of the AIME. Mr. Trevorrow is a one-time president of the Student AIME chapter at the University. He plans to go into coal production via a job with Youngstown Sheet & Tube Corp. upon graduation. The watch was presented by Charles E. Lawall, assistant vice president of the Chesapeake & Ohio RR and a member of the Old Timers' Club. Similar awards are made at some ten colleges and universities by the organization in order to stimulate interest in coal mining engineering.

• **Aerovent Fan Co. Inc. has released a new 16-mm sound-color film explaining the use of axial flow fans as they are currently employed in industry. The three basic types of axial flow fans are described, their inherent characteristics, and methods of testing used in modern fan engineering laboratories. Information on availability of *Industrial Axial Flow Fans* can be obtained from Aerovent Fan Co. Inc., 757 E. Ash St., Piqua, Ohio.**

Award Candidates To Be Selected

The AIME Board of Directors has authorized the committees administering all of the major awards of the Institute to proceed with the selection of candidates. These include the following:

For distinguished achievement:

James Douglas Medal, in nonferrous metallurgy

William Lawrence Saunders Medal, in mining.

Anthony F. Lucas Medal, in petroleum.

Erskine Ramsay Medal, in coal.

Robert H. Richards Award, in minerals beneficiation.

Charles F. Rand Medal, in mining administration.

Benjamin F. Fairless Award, in ferrous production and metallurgy.

J. E. Johnson, Jr. Award to a young man for pig iron metallurgy.

For best papers:

Robert W. Hunt Medal, iron and steel.

Mathewson Medal, physical metallurgy.

Robert Peele Award, mining, geology, or geophysics.

Rossiter W. Raymond Award for best paper by a young man.

In general, nominations for medalists must be made by members of the respective award committees, but all AIME members are invited to submit to the committees the names and records of men they believe should be considered.

AIME Board Awaits New Building Report

The AIME Board of Directors at the last meeting decided that further study should be made on the best location for a new engineering building.

As a result the Pittsburgh offer is being held in abeyance. A full report on the building situation will appear in the August issue of MINING ENGINEERING.

MINING BRANCH MEMBERSHIP DRIVE

One of the best ideas submitted for the Mining Branch membership drive is the use of testimonials. If prospective members could be shown the personal advantages that would accrue to them through membership in AIME, we might overcome some of their indecision about joining. We should look for members who are best equipped to write convincingly and have them tell us in a few short words just what personal and professional advantages they have derived from membership. We should seek out such prominent members as AIME President H. DeWitt Smith, and also some of the younger members. If these testimonials were submitted to the Local Section membership chairman, and through them to the National Membership Committee, a selection might be made of the best letters to reprint for this sales job.

Another idea, submitted at the National Membership Committee meeting in Chicago, could be carried out on the Local Section level: The recent article in MINING ENGINEERING on the number of students enrolled in engineering curricula shows a decided drop in mining and metallurgical fields. The situation is getting dangerous, and our efforts should be bent to foster the engineering vocation wherever possible. Appeals to juniors and seniors in high schools to enter engineering are too late. By this time the student is too far committed in his course of studies to take the prerequisites for an engineering education. These appeals should be made to the high school freshmen and sophomores, and to science teachers in grade schools and high schools. It is up to the Local Sections to establish student relations and activities to foster these careers. It is up to them to encourage these science teachers who, after all, will influence the minds of these young men. The membership committee, as a whole, is planning activities for the future, but to be effective this takes considerable time. In the interim the Local Sections could carry the ball. Remarkable results have been achieved where this has been attempted.

We urge all members with ideas on this subject to submit them to their Local Section membership chairman or to the National Steering Committee. It is only by a joint, coordinated, and thorough effort that we will achieve that which we are seeking—the ingress of new blood into our stream of membership life.

*C. E. Golson**

*Vice Chairman, AIME National Membership Committee.

Metals Branch Secretary Appointed

The new man behind the work-laden desk of the Metals Branch Secretary is Robert William Shearman. Mr. Shearman thus assumes the role left vacant by the promotion of Ernest Kirkendall to Secretary of the Institute.

The son of a mining engineer, Mr. Shearman is a native of Palmerton, Pa., and a graduate of the Lawrenceville School and Princeton University. He graduated from the latter school in 1937 with a Bachelor's degree in chemistry. Graduate courses from Polytechnic Institute of Brooklyn, Pennsylvania State College (now University) Extension, Harvard University, Columbia University, and New York Institute of Finance filled in additional background in economics, metallurgy and chemistry.

Before joining the AIME staff, Mr. Shearman was with Opinion Builders Inc., New York City public relations firm, where he specialized in technical publicity.

Following two years with Pittsburgh Plate Glass Co., he was employed by Bethlehem Steel Co. as a metallurgical observer, working in the open hearth and electric furnace shops. From 1946 to 1951 Mr. Shearman was with Union Carbide & Carbon Corp. He created advertising and publicity material for the Alloys and Metals Div., working on products of the Electro Metallurgical Co. and Haynes Stellite Co. He also worked on the corporation's annual report. Mr. Shearman later went to the Industrial Gases Div., working on process and products publicity for the Linde Air Products Co., covering oxygen in steel production, jet-piercing of taconite ores, welding equipment and processes, and powder-cutting and scarfing. He assisted in the work of the Program, Publicity, and Arrangements Committee of the International Acetylene Assn. during that period.

In 1951 he was recalled to the U. S. Air Force, but returned to Union Carbide in 1953 to become supervisor and later assistant division manager of the General Activities Div. of the General Publicity Dept.

Mr. Shearman first entered the armed services as a Medical Corps private in 1941, rising to sergeant. After attending officer candidate school at Edgewood Arsenal, Mr. Shearman stayed on as a Chemical Warfare OCS instructor. Later he entered the Air Force and trained at Air Force Weather School and Air Force Intelligence School. As a combat intelligence officer in the Pacific Theater, he went from lieutenant to captain. It was as a member of the Air Force Reserve that he was recalled to duty in 1951. By that time he had risen to major, a rank he now holds.

ROBERT W. SHEARMAN

One of Mr. Shearman's abiding interests is hiking. He hopes someday to cover the entire Appalachian Trail from Maine to Georgia. He sees it as a plan for some time in the dim future. Mr. Shearman has hiked in the Green and White Mountain Ranges of New England, tramped through Colorado, and has done considerable walking in Europe and Canada. He is a member of the Appalachian Mountain Club. In addition to European travels, Mr. Shearman has been to Mexico.

A number of technical and non-technical articles over his byline have appeared in newspapers, magazines, and journals. Married in 1954 to the former Dorothy French Dodge of Mountain Lakes, N. J., Mr. Shearman makes his home at 2 Stuyvesant Oval, New York City.

H. R. Hanley Serves As Formosa Advisor

Prof. H. R. Hanley, lately of the Missouri School of Mines, and a member of the St. Louis Section, is in Formosa as advisor to the mining and metallurgy dept., Taiwan College of Engineering.

He is faced with the task of setting up a mining and metallurgical dept. for the school from scratch. In addition to setting up an instruction program, Professor Hanley, who is a Legion of Honor Member of the AIME, is also charged with procurement.

One of his greatest problems is the lack of catalogs. He is making a plea to manufacturers to fill the gap. Those who can help should respond directly to: Prof. H. R. Hanley, Purdue Team, c/o Army Section, Artillery School, APO 63, c/o Postmaster, San Francisco, Calif.

Professor Hanley seeks literature covering every conceivable item used in the metallurgical and mining fields.

PERSONALS

A. I. GRABOWSKY

A. I. Grabowsky, mining geologist, Corporacíon Minera de Bolivia, La Paz, Bolivia, is mine superintendent of the Calpa gold mine, Consorcio Minero del Peru S.A., Nazca, Peru.

Oscar F. Tangel is division chief, Battelle Memorial Institute, Columbus, Ohio.

Theodore Marvin was re-elected president and chairman of the board, Michigan Chemical Corp., St. Louis, Mich., at its annual organization meeting in Detroit.

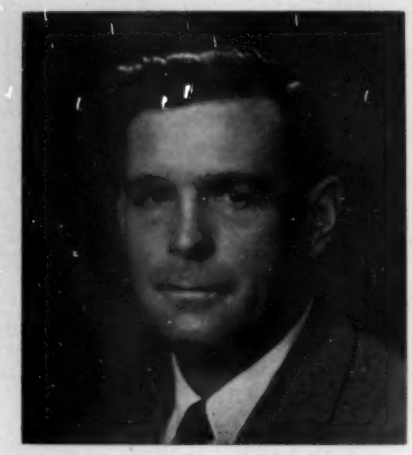
E. S. Beebe is plant superintendent, Humphreys Gold Corp., Lawtey, Fla. He was assistant to superintendent of production at Starke, Fla.

Augustus B. Kinzel has succeeded **George O. Curme, Jr.,** as vice president, research, Union Carbide and Carbon Corp., New York. Mr. Kinzel has been actively engaged in research work with Union Carbide since 1926, when he joined Electro Metallurgical Co. as a research metallurgist. He was appointed director of research of UC&C in 1954. Mr. Kinzel is a Vice President of the AIME.

Maurice Nelles, director of research and diversification, Technicolor Motion Picture Corp., Hollywood, Calif., has received a Doctor of Science degree from the University of South Dakota. Mr. Nelles was graduated from the university in 1928.

Lester F. Bishop, production foreman, The Anaconda Co., Butte, Mont., recently received the degree of Engineer of Mines from the Montana School of Mines. **Frank W. Bowdish,** University of Kansas, and **Gailen T. Vandel,** general superintendent of concentrators, Cerro de Pasco Copper Corp., La Oroya, Peru, received the degree of Mineral Dressing Engineer.

Stanley M. Mercier is manager of Jeffrey Mfg. Co., San Francisco.



GEORGE D. WINANS

George D. Winans has opened a private practice in mining engineering at 2631 E. 20th St., Tucson, Ariz. He is particularly interested in working on problems of economic mine operation and improvement in mining practice. Mr. Winans was graduated from the Montana School of Mines in 1942. He spent four years in the U. S. Navy as ordnance officer. Mr. Winans has held various positions in the mining field, including that of mining and safety engineer, Federal Mining Co., Wallace, Idaho, mine superintendent, Lovitt Mining Co., Wenatchee, Wash., and draw boss, Miami Copper Co., Miami, Ariz. His most recent position was mining engineer, shift boss, Banner Mining Co., Tucson.

Adrian E. Albrethsen, assayer, Sullivan Mining Co., electrolytic zinc plant, Kellogg, Idaho, is with The Anaconda Co., Butte, Mont.

Webster F. Stickney, graduate assistant, geology dept., University of Tennessee, is geologist, American Zinc Co., Mascot, Tenn. He is working on surface exploration.

Grover C. Dillman, president, Michigan College of Mining and Technology, Houghton, Mich., conferred the honorary degree of Doctor of Engineering on **Ross Dudley Leisk** at the college commencement ceremonies. Mr. Leisk is vice president and general manager, Sunshine Mining Co., Kellogg, Idaho, and president of the Idaho Mining Assn. He is a graduate of Michigan Tech.

Franklin H. Sharp, formerly mill superintendent for Alder Gold-Copper Co., is metallurgist with Sunshine Mining Co., Osburn, Idaho.

Koehler S. Stout, chief, mining div., Montana Bureau of Mines & Geology, Butte, Mont., is the author of *Practical Guide for Prospectors and Small-Mine Operators in Montana.* *(See page 601.)* Mr. Stout was graduated from the Montana School of Mines with a B.S. degree in mining engineering and an M.S. degree in geological engineering in 1949.

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R. R. BRYAN, JR.

Russell R. Bryan, Jr., has formed an association of Latin American mining and construction consultants. His address is 1009 Oxford St., Berkeley, Calif. Mr. Bryan was mine superintendent, Orinoco Mining Co., Ciudad Bolivar, Venezuela. Since 1940 he has been engaged in Latin American mining activities and in 1948 was geologist and mining engineer, U. S. Steel Corp., for Venezuelan iron ore exploration. Mr. Bryan has been closely associated with this project, which was initiated by the Oliver Iron Mining Co. and is now operated by U. S. Steel's subsidiary, the Orinoco Mining Co. During the summer Mr. Bryan will make an extensive trip through Latin America and the U. S., visiting mining and construction projects and studying the latest developments in equipment and methods.

Charles A. Stokes, director of research & development, Godfrey L. Cabot Inc., Cambridge, Mass., has been elected to the board of the Industrial Research Institute Inc., New York, for a three-year term.

F. F. Netzeband, U. S. Bureau of Mines, Amarillo, Texas, is now chief, Mineral Statistics Section, Region IV, USBM, Bartlesville, Okla.

John V. Hill, formerly chief laboratory technician, has been appointed manager of the mineral testing laboratory, Western Machinery Co., San Francisco.

Thomas J. Ballard and **Quentin E. Conklin** are the authors of *The Uranium Prospector's Guide*, recently published by Harper & Bros. They are mining engineers, Uranium Prospectors Co. Ltd., Grand Junction, Colo. and were formerly with the Operations Office, AEC, Grand Junction, Colo. Mr. Ballard graduated from the University of Alabama and has been employed in the mining industry in various capacities from sampler to superintendent. Mr. Conklin graduated from the South Dakota School of Mines in 1930 and since then has worked in mining in the West and in South America. *(See page 600.)*

Frank M. Makarinsky, Sudbury, Ont., recent graduate, Michigan College of Mining and Technology, Houghton, Mich., will join Falconbridge Nickel Mines Ltd., Falconbridge, Ont.

Edwin J. Westerman and **Sam Worcester,** both of Butte, Mont., and **Moshe Sheinkin** of Holon, Israel, students at Montana School of Mines, have recently received awards. Mr. Westerman received a summer scholarship in metallurgy and science of metals given by the Rensselaer Polytechnic Institute. Mr. Worcester was given the $400.00 American Society of Metals Scholarship, and Mr. Sheinkin was awarded the $400.00 AIME Woman's Auxiliary Scholarship. **J. R. Van Pelt,** president, Montana School of Mines, presented the Montana Intercollegiate Forensics Debate Cup for 1954 to the winning Mines team. Members of the team, coached by **Walter T. Scott,** were **Marvin Lanphere,** Spokane, Wash., **Lawrence McCarthy,** Butte, Mont., **James Goodrich,** Darby, Mont., and **Joseph LaComb,** Basin, Mont.

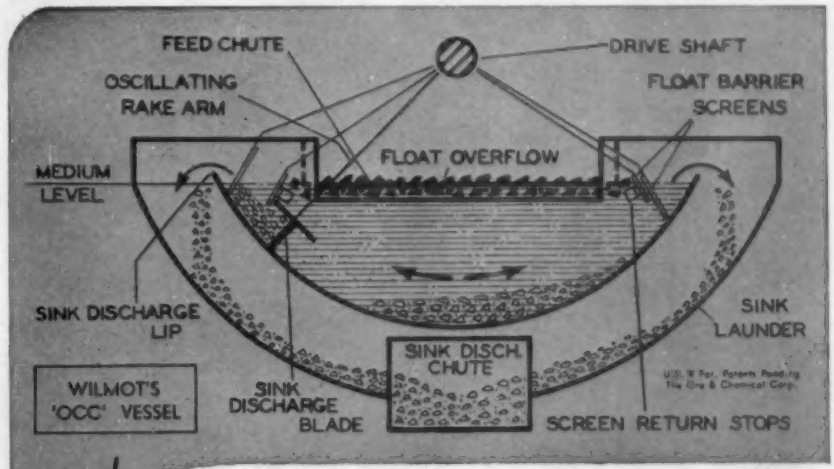
Walter Bannister, mining engineer, Canadian Johns-Manville Ltd., Matheson, Ont., has been appointed senior planning engineer, engineering dept., Steep Rock Iron Mines Ltd., Steep Rock Lake, Ont. He will plan future underground operations of the company.

TOGAN S. ONAY

Togan S. Onay, chief engineer, Mortas Mining & Trade Co., Balikesir, Turkey, has been nominated director and chairman of the Turk Mineral ve Endustri Ltd. Co., Ankara, Turkey, which operates the lignite mines of Koskdere and Kulogullar near Aydin.

Donald T. McMillan, The Fresnillo Co., Fresnillo, Zacatecas, Mexico, is geologist with the American Metal Co. Ltd., Denver.

W. T. Swensen, exploration dept., The Anaconda Co., Toronto, has been assigned to eastern Canada and heads the recently reactivated Frontenac Exploration & Development Co. office, Toronto.



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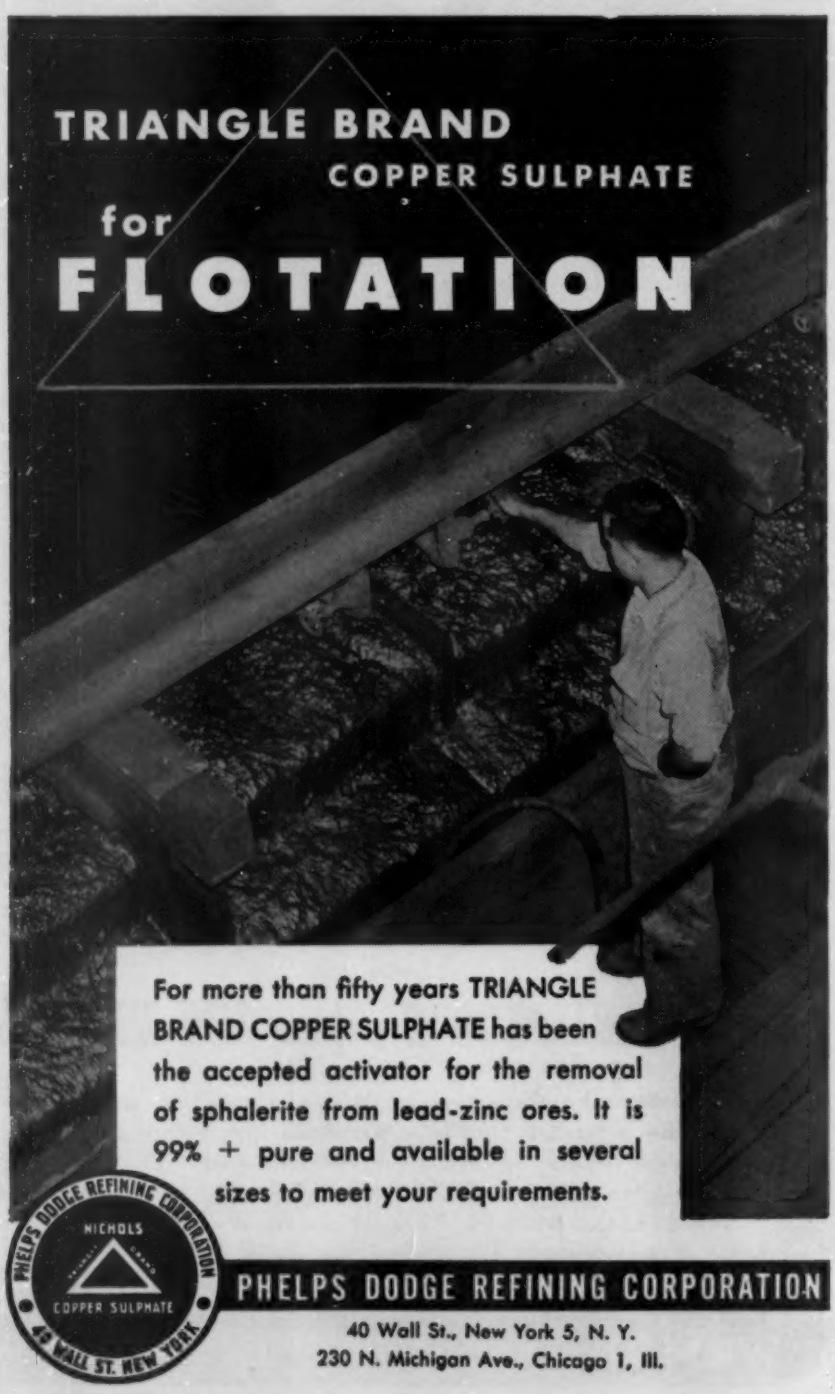
Robert H. Ashlock, mining geologist, New Jersey Zinc Co., Ely, Nev., is now with U. S. Smelting Refining & Mining Co., Salt Lake City.

John J. Reiff, chief geologist, Lone Star Steel Co., Lone Star, Texas, has joined H. & H. Exploration, Grand Junction, Colo.

W. T. Marston, manager, Western Industrial Div., The Dorr Co., Englewood, Colo., has been transferred to the western headquarters of the Sanitary, Filtration, and Industrial Divisions of Dorr-Oliver Inc., Oakland, Calif. This move resulted from the merger of The Dorr Co. and Oliver United Filters in January.

Paul H. Floyd, formerly assistant mill superintendent, Sunshine Mining Co., Kellogg, Idaho, is the proprietor of Mineral Recovery & Engineering Co., Wallace, Idaho, a new company concerned with the purchase and processing of off-grade tungsten concentrates to meet Government stock-pile specifications; also mineral dressing consulting.

Donald J. McPherson, supervisor, nonferrous metallurgy section, Armour Research Foundation, Illinois Institute of Technology, Chicago, is assistant manager of the metals research dept. Mr. McPherson joined the Foundation as a research metallurgist in March 1950.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ALLEN R. ROWEN

Allen R. Rowen is sales engineer and head of the lightweight aggregate section of the new Dwight-Lloyd Div., McDowell Co. Inc., Cleveland. Mr. Rowen was sales manager, Sintering Machinery Corp., which was recently acquired by McDowell. During World War II he was on active duty with the U. S. Navy.

Gordon E. Pflug, assayer, American Smelting & Refining Co., Selby, Calif., is junior mine engineer, Riverside Cement Co., Riverside, Calif.

S. K. Droubay, general manager, United Park Mines Co., Heber, Utah, is chairman of the program committee planning the American Mining Congress in Las Vegas, Nev., October 10 to 13.

Lars E. Ekholm, manager of sales, Climax Molybdenum Co., New York, has announced the appointment of **John F. Robb,** Pittsburgh, and **Vernon H. Patterson,** Chicago, to executive positions in the sales dept. Mr. Robb is head of steel industry sales and Mr. Patterson is manager of foundry sales. Both appointments are national in scope.

Ronald J. E. Thomas of Newcastle-on-Tyne, England, is with Gambian Minerals Ltd., Gambia, British West Africa. He was formerly mining engineer and chief surveyor, Amalgamated Banket Areas, Tarkwa, Gold Coast Colony, British West Africa.

John Charles Richards is geologist, City of Tacoma Light Div., Tacoma, Wash. He was formerly with the Corps of Engineers, Newport, Wash.

Edward L. Newcomb is serving as staff geologist, Denver Exploration Branch, Div. of Raw Materials, U. S. Atomic Energy Commission. He was with the Mineral Deposits Branch, U. S. Geological Survey, Washington, D. C.

Raymond K. Bowden, director of quality surveys, U. S. Steel Corp., Pittsburgh, and **Theodore J. Kauer,** chief engineer of the Ohio Turnpike Commission, Columbus, Ohio, received professional engineer degrees at Ohio State University's commencement exercises on June 10.

ALFRED L. PENHALE

Alfred Lloyd Penhale, president Asbestos Corp. Ltd., Thetford Mines, Quebec, has been elected president for 1955 to 1956 of the Canadian Institute of Mining and Metallurgy. A member of the CIM since 1937, Mr. Penhale has been active in the affairs of the Thetford Mines Branch, of which he is a past chairman.

Roy H. Glover, vice president and general counsel, The Anaconda Co., Butte, Mont., has been named board chairman. Born in Goldendale, Wash., in 1890, he received a law degree from the University of Oregon in 1915 and first practiced in Portland, Ore. He was admitted to the Montana bar in 1918 and practiced in that state until he joined Anaconda in 1943. Mr. Glover succeeds **Cornelius F. Kelley** who has resigned after 54 years of service with Anaconda.

A. D. Bryant, formerly vice president, Standard Silica Corp. of Ottawa, Ill., is manager of Silica Sand Corp., Ottawa, Minn.

Charles C. Hilton, director, industrial relations, U. S. Smelting Refining & Mining Co., Salt Lake City, has been named to a commission to study relationships of local government units in Utah.

George B. Kneass, Jr., is mineral plant supervisor, Foote Mineral Co., Exton, Pa. Mr. Kneass has been with the company since 1951. For two years he was mine assistant at the Sunbright, Va., plant.

Eugene N. Cameron of the University of Wisconsin has gone to the Union of South Africa for six weeks to two months as a consulting geologist for Union Carbon & Carbide Corp., New York. It is his sixth visit to Africa.

C. Harry Benedict is the author of *Lake Superior Milling Practice* recently published by Michigan College of Mining & Technology Press, Houghton, Mich. *(See page 600.)* Mr. Benedict was chief metallurgist, Calumet & Hecla Inc., Lake Linden, Mich., and received the AIME Robert H. Richards Award in 1954.

Christian F. Beukema, president, Michigan Limestone Div., U. S. Steel Corp., Detroit, and **Maurice J. Day,** director of research & development, Crucible Steel Co. of America, Pittsburgh, were among eight of America's outstanding engineers who received special awards at the symposium sponsored by Michigan State College held in celebration of Michigan State's centenary.

W. Maxwell Parris, assistant chief, Light Metals Div., Battelle Memorial Institute, Columbus, Ohio, is senior metallurgist, Titanium Metals Corp. of America, Henderson, Nev.

Henry A. Dierks, Glen Alden Coal Co., Kingston, Pa., has gone to Yugoslavia to carry out a contract for Pierce Management Inc., Scranton, Pa., with the Government of Yugoslavia. He will lead a team of eight practical operating men on a project for increasing the productivity of Yugoslav coal mines.

Raymond G. Sullivan, vice president and general manager, Minerals & Engineering Co., Grand Junction, Colo., was re-elected vice president and director, Continental Uranium Inc., Chicago.

Edward Arthur is the author of *Let's Go Prospecting!* which was published in 1954 and is now in its fourth printing. Mr. Arthur is Mining Commissioner, Los Angeles Chamber of Commerce, Los Angeles. *(See page 601.)*

Frank A. Ayer, mining engineer and consultant, New York, is president for 1955 of the Columbia Engineering School Alumni Assn. In 1954 Mr. Ayer received the Egleston Medal, Columbia's highest award for engineering. He is an internationally known engineer and has operated mines in Mexico and Africa as well as in the U. S. During World War I he served as a captain commanding an Air Squadron, and during World War II was chief for primary copper production, War Production Board. Mr. Ayer is an expert on mine safety. Two of his mines in Mexico and Arizona won the James Douglas Memorial Safety Trophy for eight consecutive years. He now has a consulting practice in New York. Mr. Ayer succeeds **Percy E. Landolt,** consulting chemical engineer, New York.

P. Sánchez Mejorada, geologist, Cía. Minera de Peñoles S. A., who received a Sloan Fellowship to the Executive Development Program of the School of Industrial Management and went to MIT a year ago, will return to company headquarters in Monterrey, Mexico, this summer.

Robert B. Ford, mining geologist, has opened an office in Riverton, Wyo. Mr. Ford was geologist, Pickands, Mather & Co., Crystal Falls, Mich. He is a graduate of the University of Wisconsin and has contributed articles to *Economic Geology* and other technical publications.

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James W. Franklin, engineer and resident representative, Lucius Pitkin Inc., New York, is assistant editor, *Engineering & Mining Journal,* New York.

Donald H. Bailey is geologist with the International Nickel Co. of Canada Ltd., Creighton Mine, Ont. Mr. Bailey was graduated from the Missouri School of Mines in January.

Jack B. Graham, ground-water geologist, is a partner in the firm of Leggette, Brashears & Graham, New York. After graduating from the University of Iowa with a Ph.D. degree in geology in 1942, Mr. Graham joined the Ground-Water Branch of the U. S. Geological Survey, and in 1952 became chief, Water Utilization Section, Technical Coordination Branch. He has been with Leggette & Brashears since 1954.

John A. Brown, chief geologist, Minnesota Mining & Manufacturing Co., St. Paul, will head the new geology dept. Mr. Brown joined the company in 1933 and has been chief geologist since 1945.

Curtis Laws Wilson, dean of the Missouri School of Mines and Metallurgy at Rolla, Mo., has received an honorary degree of Doctor of Engineering from Montana School of Mines. After graduating from Montana in 1920 Mr. Wilson became assistant research engineer for Anaconda. In 1928 he received a Ph.D. from the University of Gottingen, Germany, and then returned to the Montana School of Mines as professor of metallurgy. In 1941 he became dean of the Missouri School of Mines & Metallurgy and also director of the Missouri State Mining Experiment Station. During 1953 to 1954 Mr. Wilson served on the U. S. Secretary of the Interior's Management Survey Committee.

Gordon J. Williams, geologist and dean of the College of Mining, University of Otago, Dunedin, New Zealand, is in the U. S. for six months studying mining processes. He gave a lecture at the University of Minnesota commencement exercises and prior to that visited California, Nevada, Arizona, and New Mexico. Mr. Williams then went to Colorado to spend several weeks with the AEC before going to England.

WILLIAM S. ROW

James Y. Murdoch, president, Kerr-Addison Gold Mines Ltd., Virginiatown, Ont., has announced the election of **William Stanley Row** to the board of directors and his appointment as executive vice president. **J. L. Ramsell** was appointed manager, and **R. J. Beggs,** assistant manager. After graduating from McGill University in 1927, Mr. Row went to Cerro de Pasco Copper Corp., Peru, and three years later joined the engineering staff of Lake Shore Gold Mines Ltd. In 1937 he became manager, Kerr-Addison Gold Mines Ltd. In 1950 to 1951 he was president of the Ontario Mining Assn.

Erik Ryd has been appointed technical director of the Atlas Diesel Co. Ltd. world organization, which has its headquarters in Stockholm, Sweden. Mr. Ryd is probably best known for the part he played in the development of the Swedish method of tunnelling by producing an effective lightweight rock drill. Since 1942 he has been responsible for Atlas world sales and has made many visits to Canadian Copco, Copco Eastern and Copco Pacific, the three Atlas companies in North America. **J. A. Perham** has been appointed sales director for the Atlas world organization. Since 1952 Mr. Perham has been managing director for the organization in Britain. A graduate from McGill University, Mr. Perham was with International Nickel Co. of Canada Ltd. before joining Canadian Copco Ltd., subsidiary of the Atlas organization, in 1949.

Stanley McDougall, manager of mines, Bunker Hill & Sullivan Co., Kellogg, Idaho, has announced the promotion of **Joseph E. Gordon,** mine foreman, to assistant mine superintendent.

William T. Nightingale, president, Mountain Fuel Supply Co., Salt Lake City, has been awarded an honorary Doctor of Laws degree by the University of Wyoming. Mr. Nightingale is president of the Salt Lake Chamber of Commerce. A graduate of the University of Washington, Mr. Nightingale has done geological and mining work in many parts of the world.

William J. Owen, manager, William J. Owen Associates, Moab, Utah, is president, Moab Mines Inc., Moab, a new uranium corporation. Mr. Owen and **Robert R. Norman,** consulting geologist, Moab, will direct the activities of the company.

MEMBERSHIP

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Total AIME membership on May 31, 1955 was 22,664; in addition 1804 Student Associates were enrolled.

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Arizona
Ajo—Caton, Warren D. (R. C/S—S-M)
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Prescott—Gemmill, Mark (M)
Ray—Kast, Rene F. (C/S—A-M)
Silver Bell—Dopson, Gaylord W. (R. C/S—S-J)

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Denver—Van Sant, Joel N. (R. C/S—J-M)
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Grand Junction—Graber, Elroy A. (C/S—A-M)
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Grand Junction—Pruess, Robert C. (R. C/S—J-M)
District of Columbia
Washington—Prud'homme, Hector C. (R. C/S—J-M)
Florida
Bartow—Garcia, Raymond G. (J)
Keystone Heights——Sullivan, Daniel J. (M)
Mulberry—Wiggins, Vesper J. (M)
Orlando—Duttweiler, Henry S. (M)
Idaho
Moscow—Carmichael, Virgil W. (C/S—A-M)
Indiana
Hammond—Sheets, Cleo B. (M)
Iowa
Malvern—Donner, Donald L. (R. C/S—S-J)
Michigan
Detroit—Tillman, John R. (J)
White Pine—Samuelson, Bengt A. (M)
Minnesota
Marble—Wilson, David H. (M)
Virginia—Steel, James S. (M)
Montana
Basin—Criswell, Wilbur F. (R. C/S—A-M)
Nevada
Kimberly—Wallace, Arlin G. (R. C/S—S-J)
Red House—Glover, James H. (R. M)
New Jersey
Waldwick—Brown, Ralph L. (M)

New Mexico
Albuquerque—Booth, John R. (M)
Albuquerque—Hardin, Marion M. (M)
Albuquerque—Wolfe, Harold D. (M)
Grants—Coudray, Ray M. (J)
New York
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Oregon
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Pennsylvania
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Pittsburgh—Shallenberger, John M. (R. C/S—S-J)
Utah
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Salt Lake City—Shaw, Wayne L. (A)
Washington
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Spokane—Larson, Roy H. (R. C/S—S-M)
Spokane—Pettibone, Michael H. (J)
West Virginia
Mount Hope—Snyder, DeWitt C. (A)
British West Indies
Jamaica—Tretzel, Donald C. (M)
Canada
Ont., Kirkland Lake—Clark, John H. (A)
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Surinam—Guilonard, J. D. S. (M)
England
Chesterfield—Doris, George L. (J)
Sanderstead, Surrey—White, Norman C. (M)
France
Porspoder, Finistère—Magueur, Michel J. (A)

OBITUARIES

Charles J. Adami (Member 1912) died in the New York Hospital in New York on Mar. 28, 1955 following a brief illness. He was born in Helena, Mont., July 12, 1877. After graduating from high school Mr. Adami attended Colorado School of Mines from which he received the degree of Engineer of Mines in 1899. He was first employed in Butte as an engineer with Boston & Montana Mining Co. Later he was associated with Butte & Boston Mining Co., Colorado Silver Mining Co., and Anaconda Mining Co. He was foreman of the Grey Rock and Gagnon mines prior to moving to the Georgetown Lake area, where he became superintendent of the famous Cable Lease Mining Co.'s gold property at Cable, Mont. In 1907 he went to Missouri as superintendent of mines for the Federal Lead Co. at Flat River. Four years later he became superintendent of Doe Run Lead Co. and assistant general superintendent of mines for St. Joseph Lead Co. In 1916 he was made manager of St. Joseph Lead Co. at Bonne Terre, Mo., and in 1928 he was made technical adviser to the company's president. Following 1930 Mr. Adami maintained a consulting practice until his retirement several years ago. In 1949 the Colorado School of Mines awarded him a medal for distinguished achievement in the mineral industry field.

Surviving relatives include his widow, Mrs. Elizabeth Florence Adami in New York; son-in-law and daughter, Mr. and Mrs. Charles Webb, Denver; daughter, Mrs. Robert H. Gross, Albuquerque, N. M.; brothers, Henry C. Adami of Wallace, Idaho, who was formerly associated with the Federal Lead Co., and Dean A. E. Adami, vice president of Montana School of Mines, Butte; brothers-in-law and sisters, Mr. and Mrs. D. J. Ragen of East Helena, Mr. and Mrs. J. S. Higgins of Denver, and a sister, Mrs. Elizabeth Williamson of Helena, Mont., in addition to several nieces, nephews, and grandchildren in Colorado, New Mexico, Montana, and Washington.

Thomas C. Cheasley (Member 1941), vice president, Sinclair Coal Co., Kansas City, and nationally prominent fuel and combustion engineer died of a heart attack Mar. 17, 1955 at his home in Fort Lauderdale, Fla. Mr. Cheasley was an author and holder of several patents. He was born in London in 1889 and attended the Engineering College of the London Collegiate Institute in Canada and completed University of Illinois extension courses in engineering. His early experience was gained in Detroit where he worked for Ford Motor Co. and later for Detroit Wire Wheel Co. During World War II Mr. Cheasley was supervising engineer of the National Fuel Efficiency Council and for the U. S. Bureau of Mines. For several years he served as chairman of the AIME Open Pit Mining Methods Committee and as a member of the Gasification Committee. Last year he served as chairman of the Percy Nicholls Award Committee of ASME-AIME after being a member of that committee for four years.

Harold McLeod Cobb (Legion of Honor Member 1903) died Aug. 25, 1954. He was president and manager, Cía. Minera El Palero S.A., Guanaceví, Durango, Mexico. Mr. Cobb was born in New Jersey in 1877. He

Necrology

Date Elected	Name	Date of Death
1952	G. E. Allen	Unknown
1916	Barclay G. Anderson	May 16, 1955
1940	Crosby F. Barker, Jr.	Unknown
1948	John G. Bartram	Feb. 1955
1918	George B. Bassett	Unknown
1912	Quincy Bent	May 5, 1955
1901	James F. Brophy	Unknown
1914	W. C. Campbell	Unknown
1930	Ermil Leslie Caster	Apr. 22, 1955
1948	A. Clemes	Dec. 4, 1954
1950	William H. Cooke	Mar. 29, 1954
1935	C. A. Heberlein	May 6, 1955
1908	Arthur E. Hepburn	Unknown
1943	Lafayette Herring	Mar. 3, 1955
1920	Dudley Denison Homer	May 16, 1955
1937	Julian Kennedy, Jr.	May 8, 1955
1912	Karl L. Landgrebe	May 13, 1955
1953	Paul G. Leroy	Feb. 13, 1955
1902	John H. Lidgerwood	Mar. 9, 1955
1903	J. F. McClelland	May 5, 1955
1941	John H. McElhinney	Apr. 15, 1952
1949	Jean Model	May 29, 1955
1954	Harry B. Rose	Unknown
1901	H. P. Townsend	Feb. 17, 1955

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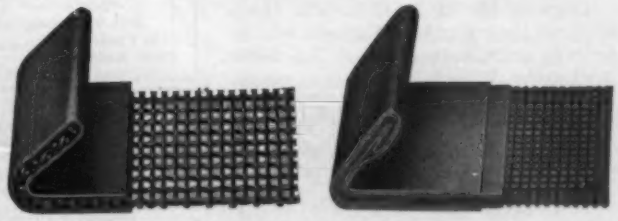

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gained his early mining experience in Colorado and acquired his technical knowledge in Ricketts & Banks in New York. For the remainder of his life, most of Mr. Cobb's mining activities were centered in Mexico.

Leland H. Hinckley (Member 1941) died Mar. 25, 1955 in Boston. He was on vacation leave from the Philippines Iron Mines, Larap, Camarines Norte, P. I. Mr. Hinckley was born in Mesa, Ariz., in 1905 and received his B.S. in mining engineering in 1928 and his E.M. in 1935 from Mackay School of Mines, University of Nevada, Reno. Following graduation in 1928 he was employed as a junior engineer with the Fresnillo Co., Zacatécas, Mexico. Mr. Hinckley was later mine superintendent, Lone Star Mining Co., Bishop, Calif.; assayer for the New California Tonapah Mining Co.; and surveyor and surface superintendent for Nevada Porphyry Gold Mines. In 1937 he was made general superintendent for Northern Mines in the Philippines and later general superintendent for Tuba Mines, Tagkawayan, Tayabas. During World War II Mr. Hinckley was regional supervisor, Mining Branch, War Production Board in Denver.

Franklin Leonard (Rocky Mountain Member 1928) died Mar. 13, 1955 in Reno, Nev. He was 84 years old. Mr. Leonard was long active in Nevada and New York mining and law circles. In New York he was twice the Democratic candidate for Congress but was not elected. He closed his New York law office last summer and returned to Reno to devote his time to his interests there.

James A. MacKillican (Member 1930) died February 1955. Mr. MacKillican was for many years manager, Meriden Iron Co., Hibbing, Minn. He was born in Jackson Port, Wis., in 1882 and received his B.S. from Michigan College of Mines in 1906. Mr. MacKillican then went to Montana where he was superintendent of the Blue Bird mine, Wilkes, for several years. From 1912 to 1913 he was city engineer, Escanaba, Mich. Mr. MacKillican became assistant superintendent, Meriden Iron Co., in 1913.

Willis W. Wiedenman

An Appreciation by
L. V. Bell

Willis W. Wiedenman (Member 1949) died Apr. 10, 1955 after an operation. He was born in Idaho in 1926. Following graduation from Idaho State University, Wiedenman has been employed during approximately the past three years as a member of the geological staff of Montana Phosphate Products Co., Garrison, Mont. He proved to be most able and thoroughly reliable, with very clear indications of a brilliant career in store as a geologist. He was married in February 1954 to Donna Finn of Deer Lodge, Mont.

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Coming Events

July 30, AIME, Adirondack Section, National Lead Co., Tahawus, N. Y. Plant tour; mining symposium.

Aug. 4, AIME, Utah Uranium Subsection, 7:30 pm, Arches Cafe, Moab.

Aug. 11-12, Denver Research Institute, Industrial Applications of X-Ray Analyses, annual symposium, University of Denver, Denver.

Aug. 27, AIME, Adirondack Section, Tupper Lake Country Club, Tupper Lake, N. Y. John F. Meyers, speaker. Golf tournament.

Sept. 24, AIME, Adirondack Section, Plattsburg Elks Club, New York. Speaker from General Electric Co. on labor relations.

Sept. 25-28, American Institute of Chemical Engineers, Lake Placid Club, Lake Placid, N. Y.

Sept. 26-30, Atomic Industrial Forum, trade fair, Sheraton-Park Hotel, Washington, D. C.

Oct. 2-5, AIME MGGD fall meeting and Black Hills regional meeting of the Ind. Min. Div., Rapid City, S. D.

Oct. 6-8, AIME, Minerals Beneficiation Div., fall meeting, **Rocky Mountain Minerals Conference,** Salt Lake City.

Oct. 10-13, American Mining Congress, Metal Mining—Industrial Minerals Convention, Las Vegas, Nev.

Oct. 13-15, Annual Drilling Symposium, School of Mines and Metallurgy and the Center for Continuation Study, University of Minnesota, Minneapolis.

Oct. 17-19, AIME, IMD, fall meeting, Adelphia Hotel, Philadelphia.

Oct. 17-21, National Safety Congress and Exposition, Conrad Hilton, Congress, Morrison, and La Salle hotels, Chicago.

Oct. 19-20, ASME, AIME, fuels conference, Neil House, Columbus, Ohio.

Oct. 27-29, AIME, Industrial Minerals Div., fall meeting, Hotel Charlotte, Charlotte, N. C.

Nov. 4, AIME, NOHC, Pittsburgh Local Sections, off-the-record meeting, Pittsburgh.

Nov. 13-18, American Society of Mechanical Engineers, Diamond Jubilee annual meeting, Congress, Hilton, and Blackstone Hotels, Chicago.

Dec. 10-16, Atomic Exposition, Public Auditorium, Cleveland. Sponsored by the American Institute of Chemical Engineers in conjunction with the Joint Nuclear Congress.

Feb. 20-23, 1956, AIME, Annual Meeting, Statler and New Yorker hotels, New York.

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2. Interboro Rapid Transit
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10. Independent Subway
11. Independent Subway
12. Interboro Rapid Transit
13. Brooklyn-Manhattan Transit
14. Interboro Rapid Transit
15. Brooklyn Battery Tunnel
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20. Lincoln Tunnel

Underground Life Lines of Manhattan

Third Lincoln Tube now brings total to 41... drilled with Ingersoll-Rand equipment

TWENTY vehicular tunnels now link Manhattan with the mainland, New Jersey and Long Island. Each tunnel consists of two separate bores. A third bore now being added to the Lincoln Tunnel will bring the total to 41. It will also keep Ingersoll-Rand's 79-year-old record intact. For here, as on all other Manhattan tubes since the very first one, Ingersoll-Rand drills have been used on the rock work.

The western end of this new Lincoln tube calls for driving through rock approximately 750 ft. of 34 ft. circular tunnel. It is being driven in two sections from the bottom of a shaft 130 ft. deep. After careful consideration of all modern tunnel driving methods, I-R Jackdrills and 1⅜" Carset Jackbits were selected for driving the top heading. The bench will be driven by Ingersoll-Rand Wagon Drills.

When it comes to drilling rock, remember that I-R can supply everything you need from the bit all the way back to the compressor. Let your Ingersoll-Rand representative help plan your next rock job. His experience may be of great value to you.

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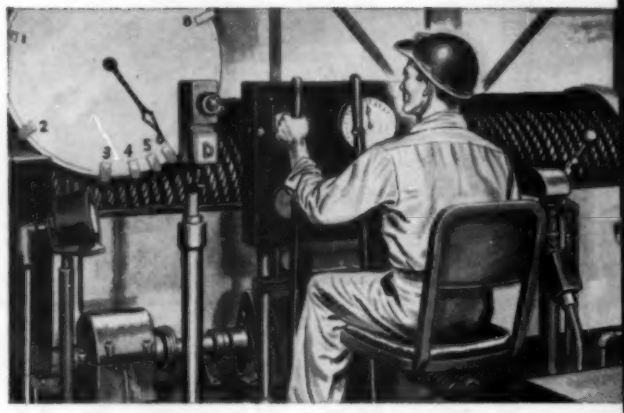

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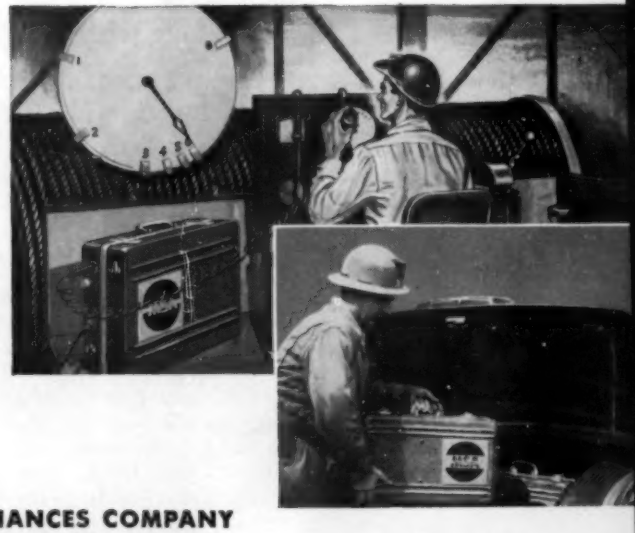

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